労災疾病研究事業費補助金

職場における腰痛の効果的な治療法に関する研究

平成26年度総括・分担研究報告書

主任研究者　松平浩

平成27年3月

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Ⅰ. 総括研究報告

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平成26年度総括研究報告書

職場における腰痛の効果的な治療法等に関する研究

研究代表者　松平浩　東京大学医学部附属病院22世紀医療センター
運動器疼痛メディカルリサーチ＆マネジメント講座

研究要旨

本研究では、世界的にみてもいまだ克服されていない腰痛対策をテーマに、特に介護看護従事労働者をターゲットとして、疫学的手法を用いたリスク因子の同定、発症予防に役立つ体操や福祉機器および両立支援手法の開発ついての取り組みを、3 年計画で包括的に推進することとした。初年度の検討結果は以下である。

1)介護施設で働く労働者は、腰痛有訴者が多く、身体的負荷のみならず、ストレス反応としての活気、疲労感、抑うつ感、身体愁訴が関連していた。

2)高齢者介護施設で働く介護職では、作業に支障をきたす腰痛（作業支障腰痛）の訴えが、自覚的労働負荷が強く夜勤時間が長くなるにつれて増加した。

3)作業支障腰痛が遷延することのリスク要因として、仕事や生活での満足度が低い，働きがいが乏しい、不安感が強いといった、職場を主とする心理社会的要因が挙げらた。

4)開発した福祉機器（新たなコンセプトの体幹装具）は、脊柱起立筋の活動を減少させ,体幹深部筋（腹横筋）の筋厚を増大させたことから、腰痛予防に有益な可能性が高いことが示唆された。

5)産業理学療法士によるメール指導は、相談者の腰痛予防のための行動変容を促すのに効果的であり、両立支援手法の一手段となる可能性があると思われた。

来年度以降、さらに包括的な研究を発展させ、職場における効果的な腰痛対策の確立を目指す予定である。

＜研究分担者＞

東京大学医学部附属病院22世紀医療センター
運動器疼痛メディカルリサーチ＆マネジメント講座特任助教　岡敬之

東京大学大学院医学系研究科成人看護学講師
高井ゆかり

関西福祉科学大学理学療法学教授　野村卓生

国際医療福祉大学小田原保健医療学部大学院福祉支援工学分野専任講師　勝平純司

横浜労災病院整形外科部長　三好光太

金城大学医療健康学部教授　小山善子

＜研究協力者＞

東京大学医学系研究科精神保健学/精神看護学分野　准教授　島津明人

労働安全衛生総合研究所上席研究員　高橋正也

労働安全衛生総合研究所　岩切一幸

川村義肢株式会社製造本部製造管理部製造開発課　安井匡

東海大学医学部生体構造機能学講師　金沢輝久

東京大学医学部附属病院22世紀医療センター運動器疼痛メディカルリサーチ＆マネジメント講座
登録研究員　川又　華代

長崎労災病院副院長　小西宏昭

千葉労災病院副院長　山縣正庸

関東労災病院副院長　岡﨑裕司

関西労災病院治療就労両立支援センター産業理学療法士　高野賢一郎

大阪労災病院治療就労両立支援センター産業理学療法士　浅田史成

中国労災病院治療就労両立支援センター産業理学療法士　仁田靖彦

東北労災病院治療就労両立支援センター産業理学療法士　佐藤友則

関西福祉科学大学理学療法学　明崎禎輝

株式会社 OH コンシェルジュ代表産業医　東川麻子

A. 研究目的

厚生労働省が公表する「国民生活基礎調査の概要」において，国民の代表的愁訴（有訴者率）が，腰痛（男 1 位，女 2 位），肩こり（男 2 位，女 1 位）であることはよく知られているが、同じく厚生労働省が公表する業務上疾病発生状況等調査によると、休業 4 日以上の業務上疾病の発生件数のうち腰痛は、長年に渡り全職業性疾病の約 6 割を占め第 1 位である。平成 23 年の腰痛全届け出のうち社会福祉施設が 19%を占め、10 年で 2.7 倍という最も顕著な増加となった背景を踏まえ、19 年ぶりに改訂された「職場における腰痛予防対策指針」（平成 25 年、厚生労働省）では、重症心身障害児施設等に限定されていた適用を、福祉・医療等における介護・看護作業全般に拡大し、内容を充実させるに至った。つまり、介護・看護従事者への腰痛対策は、産業衛生領域の喫緊の課題といえる。また世界疾病負担研究にて 289 の疾患や傷病のうち、腰痛が Years Lived with Disability (YLDs)、つまり健康でない状態で生活する年数を指標とする統計のトップにランクされるなど、社会的損失や健康面への影響の大きい腰痛への対策はグローバルにも重要な課題として位置づけられている。

研究代表者は、昨年度まで行われた「労災疾病等 13 分野研究」の本分野において世界標準のエビデンスを踏まえつつ独創的な研究を展開し、近年、国際的にも評価される業績を公表してきた（13 分野研究の総括事後評価点数：5 点満点で 4.9）。

本研究では、世界的にみてもいまだ克服されていない腰痛対策に関し、臨床専門の医師のみならず産業医学・産業保健、看護、人間工学、福祉工学、統計学といった様々な分野のスペシャリストを分担研究者、研究協力者として多数招聘し、これまでの主任研究者の実績と研究基盤をさらに発展させる。特に介護看護従事労働者をターゲットとして、疫学的手法を用いたリスク因子の同定、発症予防を目的とした介入法の構築、福祉用具の開発や利用および職業と治療の両立支援法の作成を、PDCA サイクルも有効に活用しつつ包括的に推進することとした。

具体的には、３年計画で以下のサブテーマに基づき遂行する予定とした。①腰痛に関わる実態およびリスクの同定、②予防に有用な福祉機器等の開発、③介護看護従事者への予防介入法とマネジメントシステムの構築、④個人と職場の双方に有益な腰痛治療と職業生活との両立支援手法の開発、以上を踏まえた⑤労働安全衛生マネジメントシステム構築を視野に入れた提言作成。

初年度である本年度、推進した研究に関し、上①～④のサブテーマ別に報告する（⑤は最終年度課題であるため今回は省略する）。

B. 研究方法

① 腰痛に関わる実態およびリスクの同定

1) 石川県内の医療・介護施設 125 か所に調査用紙を送り、本調査研究の趣意に賛同を得た医療・介護施設 95 か所及びそこで働く無作為に

選定された1施設20名を対象とし､腰痛状況、職業性ストレス簡易調査票を含む多面的な自記式質問紙による実態調査を行った。

2) 社会福祉懇談会の会員である介護施設（50施設、4,105 名）に対して、自記式質問紙による調査を行い、作業支障腰痛と作業負荷や勤務体制等の関連性等を検討した。

3) 前向きに追跡したコホート研究である JOB (Japan epidemiological research of Occupation-related Back pain) study の 1 年間の追跡データを用い、ベースライン時、仕事に支障のある腰痛を直近1ヶ月に経験した労働者が、１年間のフォローアップ期間に同等の腰痛を３ヶ月以上経験していた場合を遷延化と定義し､遷延化する因子を検討した。

②予防に有用な福祉機器等の開発

従来の体幹装具は装着することで体幹運動を制限することで腰部負担の軽減を目指している。しかしながら、先行研究では体幹装具装着による腰部負担の軽減効果を示すことができていない。また、体幹装具は長期間装着すると体幹周囲筋、特に側腹筋の弱化につながると指摘されている。そこで継手の抗力により胸部を前方から押す力を与えることで腹筋の活動を促通し、背筋の活動を低減する新たなコンセプトの体幹装具 Trunk solution（以下 TS）を開発し、2014年のGood Design賞を受賞した。本研究では、健常若年成人を対象とし、TSの歩行における脊柱起立筋の活動に対する効果と外した後の持ち越し効果および TS 装着時の側腹筋の筋厚を、従来の体幹装具の中で最も汎用されているダーメンコルセットと比較検討を行った。対象は健常成人男性 24 名で、TS 装着群(TS 群)とダーメンコルセット装着群(ダーメン群)の2群に、無作為に選別した。

③介護看護従事者への予防介入法とマネジメントシステムの構築

主任研究者は、勤務中多忙な介護看護従事者が簡易で即実践できる腰痛予防体操（腰を反らす“これだけ体操”）を、ポピュレーションアプローチとして実践することにより職場の腰痛状況を改善できる可能性を先行研究で示している。本研究では、産業衛生領域の喫緊の課題である腰痛予防対策を効率的に行うマネジメントシステムを構築する基盤として、簡易で即実践できる体操に加え、産業理学療法士からの科学的根拠に基づいた腰痛教育の有益性を、大規模介入比較試験により検証する。研究初年となる本年度は研究実施に必須となるプロトコールを確定することとした。全国の 12 労災病院をクラスターとして、A:対照（無介入）、B：腰椎伸展体操の普及・実践、C:B+産業理学療法士による腰痛教育・相談の実践の3群を実施するため、研究デザインを行いプロトコールを作成した。

④個人と職場の双方に有益な腰痛治療と職業生活との両立支援手法の開発

業務上疾病の約6割を占める腰痛には、人間工学的要因のみならず心理社会的要因も関与することが科学的根拠のある事項として認識され、さらには正しい情報の提供や周囲の励ます態度などは腰痛を軽快させることが明らかになりつつある。一方、腰痛予防に関しても、特定健診・保健指導で用いられるメール指導による腰痛予防効果の有効性が期待されたため、両立支援手法の一手段として産業理学療法士主導で取り組んできた。その結果、メール指導前後において労働者が各自の職務をどれほど上手にできているかを表す指標である Work Ability Index（WAI）の有意な向上、腰痛に関わる就労状況を含めた予後規定因子としてグローバルに最も重要視されている恐怖回避の思考・行動を表す Fear-Avoidance Beliefs Questionnaire（FABQ）の改善傾向を認め、産業理学療法士による腰痛予防を主軸とする両立支援を目的としたメール指導の一定の効果を確認してきた。今回は、相談者（勤労者）の事例を供覧し、相談者の腰痛予防のための行動

変容を促すことにメール指導による腰痛予防指導のあり方やその効果を考察することに加え、指導者（産業理学療法士）へのアンケートから，インターネットや携帯端末機器を利用した効果的なメール指導が効果的かを探索した。

（倫理面への配慮）

独立行政法人労働者健康福祉機および関連各労災病院、国際医療福祉大学、関西福祉科学大学、東京大学医学部附属病院の倫理審査の承認を得ている．被験者に対してはデータを ID 化して管理するなど個人情報には十分配慮している。

C. 研究結果

① 腰痛に関わる実態およびリスクの同定

1）アンケートの回答者（施設回収率 76.0%）は 1704 名で、男性 420 名、女性 1281 名（性別未回答 3 人）であった。雇用状況は、職種では介護福祉士が 48.0%、ホームヘルパー14.0%、看護師・保健師は 12.6%、理学療法士・作業療法士が 1.2%、ケアワーカー6.6%である。看護・介護業務の経験年数は 10 年以上～20 年未満が 32.3%と一番多く、ついで 5 年以上～10 年未満 26.8%、2 年以上～5 年未満 17.7%、20 年以上が 11.3%、2 年未満では 10.6%で、うち 1 年以上～2 年未満 6.0%、1 年未満 4.6%であった。腰痛状況に関してだが、過去 1 か月で腰痛がないと回答した人は 441 人（25.9%）のみで、1133 人（66.5%）の 7 割弱の人が腰痛を認めていた（以下、腰痛あり群）。腰痛有訴者をさらに分析すると、腰痛のため仕事に支障をきたしたとの回答者は 258 名（全回答者の 15.1%）にみられ、40 名（全回答者の 2.3%）が腰痛のため欠勤（休職）していた。さらに腰痛ありの人で腰痛を患わってから 3 か月以上経過している、つまり慢性化している人が 74.4%と腰痛有訴者の 2/3 を占めた。また、腰痛のため、連続して 4 日以上休んだ経験のある人は、11.2%存在した。腰痛に関連する要因を、職業性ストレス簡易調査票の項目を主に説明変数として多変量調整ロジスティック回帰分析で検討したところ、身体的負担度、ストレス反応の活気、疲労感、抑うつ感、身体的愁訴が負の方向に有意な因子であった。

2）3,155 名より回答が得られた（回答率 77%)。作業に支障をきたす腰痛の訴えは、自覚的な労働負荷が強く夜勤時間が長くなるにつれて増加した。加えて、介護職 1 名あたりの利用者数が多く夜勤時間が長いと、作業支障腰痛が増加した。

3）ベースライン時に回答した 5,310 名中，3,811 名が 1 年フォローアップに回答していた（追跡率：71.8%）。171 名にベースラインでの直近 1 カ月に仕事に支障のある腰痛があり、そのうち 46%が、看護・介護あるいは 20kg 以上の重量物を取り扱う作業に従事していた。171 名中 29 名（17.0%）がフォローアップ期間中、遷延化していた。ロジスティック回帰分析の結果、働きがい、不安感、および仕事や生活の満足度が、他要因を調整しても遷延化の有意な危険因子として挙げられた。

②予防に有用な福祉機器等の開発

体幹装具（TS)を装着することにより、歩行時の脊柱起立筋の活動が減少するとともに外した直後においてもその効果が維持された。さらには、体幹深部筋である腹横筋の筋厚が増加した。これらの効果はダーメンコルセットを装着しても認められなかった。

③介護看護従事者への予防介入とマネジメントシステムの構築（大規模介入比較試験の研究デザイン作成）

● 施設をクラスターとした無作為比較試験

●対照（無介入）、腰椎伸展体操の普及・実践、B の介入+産業理学療法士による腰痛教育・相談の実践の 3 群

●北海道中央（予定看護師数：155)、東北（421)、関東（610)、横浜（585)、新潟（261)、浜松（236)、旭（189)、大阪（662)、関西（619)、中国（363)、愛媛（180)、長崎（300)、総計 4,581 名をリクル

ート予定。以上 12 労災病院（施設）のをクラスターとし、病床・看護師数、看護師の男女数・平均年齢を割付調整因子とし、コンピューターの乱数表を用い、3 群（4 施設ごと）に無作為割付する非盲検試験

●エンドポイント：EQ-5D と腰痛に関わる医療施設での治療日数から概算した医療費から算出した QALY、腰痛の有無および仕事への支障度を勘案した腰痛 grade（重症度）の改善、直近 4 週の腰痛の程度（Numerical Rating Scale）、腰痛の自覚的改善度、腰痛予防対策の自覚的実行度、腰痛の受診状況、腰痛に対する恐怖回避思考（FABQ 身体）、Kneel Start Back スクリーニングシステムによるリスク、抑うつ（K6）、過去 30 日間の仕事のでき具合（HPQ）、労災病院検診データ。

●介入期間：1 年

●選択基準:選定された労災病院に勤務する成人（20 歳以上）看護師、本研究の趣旨に賛同し同意を得た者。

●除外基準：妊婦，あるいは妊娠の疑いがある場合、腰椎伸展により症状が誘発される腰部脊柱管狭窄症と診断されたことがある者、研究の同意を撤回した者。

<u>④個人と職場の双方に有益な腰痛治療と職業生活との両立支援手法の開発</u>

産業理学療法士によるメール指導は、相談者の腰痛予防のための行動変容を促すのに有用と思われる。

D. 考察

介護の現場では、腰痛有訴者が多く、身体的負荷のみならず、ストレス反応としての活気、疲労感、抑うつ感、身体愁訴が関連することが浮き彫りになった。

また、作業に支障をきたす腰痛の訴えは、自覚的な労働負荷が強く夜勤時間がが長くなるにつれて増加することに加え、介護職 1 名あたりの利用者数が多くかつ夜勤時間が長い場合も作業支障腰痛が増加することが示唆されたことから、介護労働に伴う身体的・精神的負荷を軽減することが夜勤の短縮とともに重要になると考えられた。そのためには，福祉機器の活用や，施設内で安全衛生のレベルを向上させるマネジメントシステムの確立などが求められる。

作業に支障をきたす腰痛が遷延化することに影響する要因は、仕事や生活での満足度が低い、働きがいが乏しい、不安感が強いといった、職場を主とする心理社会的要因であることが明らかになったが、本知見は、欧米のエビデンスと矛盾しない。メカニズムとしては、心理社会的要因がストレッサーとなり，中脳辺縁系ドパミン・オピオイドシステムの機能異常に続発する下行性疼痛調節系や自律神経系のアンバランスに伴う痛覚過敏や局所の血流低下・筋攣縮などが考えられる。その結果として、複数の身体愁訴（いわゆる身体化、腰痛はその一症状）が出現したり遷延化する場合があるのだろう。

我が国の産業衛生分野において、人間工学的なアプローチによる腰痛の予防や対策が主流であり、重要なアプローチであることは疑いない。しかしながら、厚生労働省業務上疾病発生状況等調査にて、腰痛における休業 4 日以上の業務上疾病の発生件数をはじめとする統計データが長年にわたり好転していない現状を踏まえると、作業支障腰痛の遷延化による職場における労働力の損失を予防・緩和するための今後の対策として、心理社会的要因へのアプローチも人間工学的アプローチと並行して考慮する必要がある。今後、さらに疫学的な分析を積み重ね、リスク要因に関するエビデンスを構築する予定である。

予防に有効な福祉機器の開発に関してであるが、新たなコンセプトで開発した体幹装具（TS）を装着することにより，歩行時の脊柱起立筋の活動が減少するとともに外した直後においてもその効果が維持され、かつ、体幹深部筋である腹横筋の筋厚が増加するという従来のダーメンコルセット装着では得られない効果が認められた。脊柱起立筋の過活動は腰痛につながり，体幹深部筋

のエクササイズは腰痛予防に効果があると報告されていることから、体幹装具（TS)を装着することによる脊柱起立筋の活動を低減しながら、体幹深部筋の収縮を促通する効果は腰痛予防の福祉機器となりうると考えられた。今後は、良姿勢を含む体幹装具（TS)の効用に関し、さらに多面的に検証する予定である。

一方、介護看護に関わる作業形態は、腰椎前屈位になることが多く、これに伴う生体力学的負荷が災害性腰痛につながるリスクが少なから存在するわけであるが、そのリスクの気づきを促す福祉機器が介護看護従事者への予防介入およびマネジメントシステムを構築するうえでも不可欠と考え、現在、その試作品を開発中である。具体的には、腰部負担の数値化を目指しており、次年度には、試作品の妥当性検証を行う予定である。このような福祉機器と簡易で即実践できる腰痛予防体操のコンビネーションで、わかりやすく質の高いマネジメントシステムを提案したいと考えている。

さらには、腰痛に関わる両立支援を推進するうえで、運動器およびリハビリテーション医学の領域に加え、産業保険分野に精通している産業理学療法士が実施するメール指導は、腰痛予防のための行動変容を促すことから、その質の高いシステムを構築する予定である。

E. 結論

●介護施設で働く労働者は、腰痛有訴者が多く、身体的負荷のみならず、ストレス反応としての活気、疲労感、抑うつ感、身体愁訴が関連していた。

●高齢者介護施設で働く介護職では、作業に支障をきたす腰痛（作業負担腰痛）の訴えが、自覚的労働負荷が強く夜勤時間が長くなるにつれて増加した。

●作業負担腰痛が遷延することのリスク要因ととして、仕事や生活での満足度が低い、働きがいが乏しい、不安感が強いといった、職場を主とする心理社会的要因が挙げらた。

●開発した福祉機器（新たなコンセプトの体幹装具）は、脊柱起立筋の活動を減少させ，体幹深部筋（腹横筋）の筋厚を増大させたことから、腰痛予防に有益な可能性が高い。

●産業理学療法士によるメール指導は、相談者の腰痛予防のための行動変容を促すのに効果的であり、両立支援手法の一手段となる可能性がある。

F. 健康危険情報

該当なし

G. 研究発表

1. 論文発表

1. Matsudaira K, Kawaguchi M, Isomura T, Inuzuka K, Koga T, Miyoshi K, Konishi H. Assessment of psychosocial risk factors for the development of non-specific chronic disabling low back pain in Japanese workers-Findings from the Japan epidemiological research of Occupation-related Back pain (JOB) study. (Ind Health, 2015, in press)
2. Matsudaira K, Hiroe M, Kikkawa M, Suzuki M, Isomura T, Oka H, Hiroe K, Hiroe K. Can standing back extension exercise improve or prevent low back pain in Japanese care workers? J Man Manip Ther, 2015 (DOI: http://dx.doi.org/10.1179/2042618614Y.0000000100)
3. Hasegawa T, Katsuhira J, Matsudaira K, Iwakiri K, Maruyama H. Biomechanical Analysis of Low Back Load when Sneezing. Gait Posture 40: 670-675, 2014
4. Matsudaira K, Konishi H, Miyoshi K, Isomura T, Inuzuka K. Potential risk factors of persistent low back pain developing from mild low back pain in urban Japanese workers. PLos One 9(4): e93924, 2014
5. Matsudaira K, Kikuchi N, Murakami A, Isomura T. Psychometric properties of the Japanese version of the Fear-Avoidance Beliefs Questionnaire (FABQ). J Orthop Sci 19: 26-32, 2014
6. Yamada K, Matsudaira K, Takeshita K, Oka H, Hara N, Takagi Y. Prevalence of low back pain as the primary pain site and factors associated with low health-related quality of life in a large Japanese population: a pain-associated cross-sectional epidemiological survey. Mod Rheumatol 24: 343-348, 2014

2. 学会発表

1. Matsudaira K, Suzuki M, Sawada T, Sato E, Isomura T. Usefulness of “One Stretch”, a simple, daily, standing back extension exercise, for the prevention of onset or aggravation of low back pain in care workers. ISSLS Annual Meeting in Seoul, Korea, 2014.06.3-7
2. Matsudaira K, Sawada T, Kikuchi N,Sato E, Suzuki M. Workaholism as a risk factor for depression and disabling back pain among Japanese workers. ISSLS Annual Meeting in Seoul, Korea, 2014.06.3-7
3. Matsudaira K: New Concept of Back Pain for The 21st Century. Office Orthopedics Update 2014, Winter, Seoul, Korea, 2014.11.30
4. 松平浩：腰痛の疫学的実態 世界的な腰痛戦略を視点に入れた知見の紹介：第 22 回日本腰痛学会 千葉市、2014.11.15-16
5. 松平浩：痛みの運動療法再考：第 7 回日本運動器疼痛学会　宇部市、2014.10.25-26
   松平浩：腰痛診療再考―ペインクリニックに役立つ診断と治療の知識：第 48 回日本ペインクリニック学会　東京、2014.7.23-26
6. 松平浩：私の考える腰痛の保存療法　運動療法と薬物療法の意義を再考する－：第 43 回日本脊椎脊髄病学会　京都市、2014.4.17-19
7. 松平浩：メンタルヘルス対策が腰痛対策としても重要な理由（教育講演）：日本産業衛生学会関東地方会 第 265 回例会　東京、2014.4.26
8. 菊池徳昌、松平浩、澤田孝之、川口美佳、豊田哲巳、犬塚恭子、岡敬之：日本語版 STarT Back スクリーニングツールの計量心理学的検討. 第 22 回日本腰痛学会 千葉市、2014.11.15-16
9. 山田恵子、松平浩：小児期の精神的トラウマと成人後の慢性痛との関連：第 44 回日本慢性疼痛学会　横浜市、2015.2.27-28
10. 山田恵子、松平浩、今野弘規、北村明彦、磯博康：職場の支援・仕事の満足度と慢性痛との関連　性差の検討:第 73 回日本公衆衛生学会　宇都宮市、2014.11.5-7
11. 磯村達也、松平浩、小西宏昭：勤労者の腰痛管理　日本人勤労者を対象とした腰痛疫学研究：第 62 回日本職業・災害医学会　神戸市、2014.11.16-17
12. 高野賢一郎、松平浩：腰痛予防の新たな展開：第 62 回日本職業・災害医学会　神戸市、2014.11.16-17
13. 湯川泰紹、加藤文彦、伊藤圭吾、小西宏昭、松平浩：社会福祉施設職員における腰痛の頻度、特徴、画像診断の研究と予防対策：第 62 回日本職業・災害医学会　神戸市、2014.11.16-17
14. 高橋正也、松平浩、岩切一幸、久保智英：高齢者介護施設における介護労働者 の作業支障腰痛、不眠、精神的不調　夜勤と労働負荷の関連：第 6 回 日本臨床睡眠医学会学術集会　神戸市、2014.8.1-3

H. 知的財産権の出願・登録状況（予定を含む）

1．特許取得

なし

2．実用新案登録

なし

3．その他

Ⅱ.分担研究報告

労災疾病臨床研究事業費補助金

分担研究報告書

腰痛に関わる実態およびリスクの同定

介護職の腰痛状況および職場の心理社会的要因との関連性の検討

研究分担者　小山善子　金城大学医療健康学部

研究要旨

医療・介護職場における腰痛の状況と職場の心理社会的要因の関連を検討するため介護施設 95 か所、そこで働く看護・介護職 1704 人を対象として無記名自記式質問調査法で腰痛状況、睡眠状況、職業性ストレス簡易調査票、ストレス反応、GHQ-30 等を調査した。腰痛ありは 1133 人（66.5%）であった。職場のストレス簡易調査票でのストレスの仕事の負担度（量・質・身体的)、仕事のコントロール、 職場の対人関係、技術の活用度、環境、適性度・働きがい、支援度・上司、支援度同僚のどの項目も腰痛あり群がなし群と比べて高得点であった。ストレスによっておこる心身の症状の活気、イライラ感、疲労感、不安感、抑うつ感、身体愁訴はいずれも腰痛あり群がなし群よりも多くに見られ、特に疲労感、抑うつ感はなし群の 2 倍、身体愁訴は 4 倍も多かった。GHQ-30 の総合平均得点は 9.42±6.70 点で、腰痛なし群は 6.65±5.79、腰痛あり群 10.85±6.68 点であった。Cut-off の 7 点以上は約 6 割に見られ、介護職場は精神健康度が悪かった。睡眠時間が 5 時間未満は 6.9%に見られ、腰痛あり群では 7.7%、なし群は 5.2%あった。入眠困難、途中覚醒、早朝覚醒、朝に疲労感はいずれも腰痛あり群が、なし群より多かった。腰痛あり群となし群を単変量解析でみると、性別、年齢、仕事の量・質・身体的負担、コントロール、適性度・働きがい、支援度上司・同僚、で有意差が見られた（Ｐ＜0.01)。ストレス反応の活気、イライラ感、疲労感、不安感、抑うつ感、身体愁訴のいずれも有意差が認められた（Ｐ＜0.01)。GHQ-30 も両群間で有意差がみられた。睡眠状況では入眠困難、途中覚醒、早朝覚醒、朝の疲労感で有意差がみられた。腰痛に関連する要因は多変量解析で年齢、身体的負担度、ストレス反応の活気、疲労感、抑うつ感、身体的愁訴、GHQ-30 であった。以上の結果より、介護施設で働く労働者は、腰痛有訴者が多く、腰痛と職場のストレス、心身のストレス反応、および精神的健康度を含む全般的な健康との間には、明らかに負の関連があった。社会福祉法人の腰痛対策として、従来の環境整備、環境管理、腰痛運動だけでなく、職場のストレス対策・メンタルヘルス対策からの取り組みも必要であることが示唆された。

A.研究目的

職場において腰痛に悩む人は少なくなく、企業にとっても腰痛は労働力の低下となるもので、その予防対策は大きな課題である。軽症で就労ができても疲れやすくなり、腰痛での休業は長期化することが多く、休業が長引くと体力・気力も衰え、労働者にとっても、企業側にとっても深刻な健康問題である。

厚生労働省労働基準局調査によると平成 24 年の業務上疾病の発生件数（休業 4 日以上）は総計 7,743 人で、業務上の負傷に起因する疾病者が 5,688 人（73.4%）で、この中の 84.2%の 4,789 人が腰痛（災害性腰痛）で全業務上疾病の 61.8%を占めている。

厚生労働省は第 12 次労働災害防止計画で、労働災害による被災者数は長期的には減少しているが、第三次産業では特に社会福祉施設は過去 10 年で 2 倍以上に増加していることから、第三次産業に焦点を当て、特に災害の多い「小売業」、「社会福祉施設」、「飲食店」を最重点業種として集中的取組を実施し、また、健康確保・職業性疾病対策の重点化としてメンタルヘルス対策、過重労働対策などと並んで腰痛・熱中対策を挙げている。腰痛対策として介護施設、小売業、陸上貨物運送事業を重点的に腰痛予防教育の強化、介護機器の導入、腰痛健康診断の普及・徹底、腰痛を起こさない移動・移乗介助法の指導などにより腰痛予防手法を普及、重量物取扱い業務の腰痛予防に資する規制の導入を検討し、社会福祉施設の腰痛を含む死傷者数を 10%以上減少させることを目標値として設定している。

さらに厚生労働省は、平成 6 年に策定した「職場における腰痛予防対策指針」を 19 年ぶりに改訂した。腰痛は特定の業種のみならず、多くの業種や作業でみられるが、近年、急速な高齢化により介護の仕事での需要がますます増え、介護福祉施設における腰痛発生件数が増加している（保健衛生業の業務上の負傷に起因する疾病者 1,393 人のうち 93.2%の 1,298 人が腰痛である）。これを受け、新指針では適用対象を拡大し福祉・医療分野における介護・看護作業も対象とし、腰部に負担の少ない介護・介助法などが加えられ、またリスクアセスメントや労働安全衛生マネジメントシステム考え方も導入して健康保持増進対策を含めての腰痛予防対策の基本的な進め方を具体的に示している。

さて、腰痛の発生要因には、動作要因、環境要因、個人的要因などがあり、こうした様々な要因が総合的に重なり発生すると指摘されている。職場における腰痛を予防するには作業管理、作業環境管理、健康管理、労働衛生教育等を総合的かつ継続的におこなうことによって腰痛の発生のリスク軽減に努めることが基本と考えられ、多くの企業で腰痛予防がとられているところであるが、十分とは言えない状況である。各産業保健推進センター／連絡事務所でも産業医、産業保健スタッフ等を対象に職場の腰痛対策の研修会等を積極的に実施されつつある。

腰痛は原因によって「特異的腰痛」と「非特異的腰痛」に分類される。「特異的腰痛」は腰椎椎間板ヘルニア、腰部脊柱管狭窄症、圧迫骨折、脊椎腫瘍など病因が明確化できる腰痛で、これに対し「非特異的腰痛」はＭＲＩなど様々な検査でも原因が特定できない腰痛が該当する。腰痛者の約 85％がこの非特異的腰痛で、慢性的な腰痛、再発を繰り返す腰痛はこの非特異的腰痛といわれており、研究者たちがさまざまな角度から非特異性腰痛の解明に取り組んでいる。

近年、腰痛への心理社会的ストレスの影響が注目されているが、松平によると「非特異的腰痛」は姿勢や動作に関係する「運動器（脊椎）の不具合」と心理社会的ストレスによる「脳機能の不具合」によるものとして、腰痛への新しい視点からの腰痛予防対策を提案している。

介護職場は腰痛に加え、過酷な労働条件、ストレスフルな職場といわれている。仕事のストレスとしては上司や同僚との人間関係が大きなストレスではあるが、利用者の暴力・ハラスメント・クレーム・いじめ、利用者へのサービスなどの介護職場特有の精神的ストレス、交代勤務・長時間労働などが挙げられる。

上記で述べてきたようなことを背景に、社会福祉施設が増える中、そこで働く介護看護職の人の腰痛に対する対策は喫緊な課題である。腰痛と仕事のストレスとの関連性を明らかにすることは今後の腰痛対策へのヒントになる。今回、「医療・介護職場における腰痛の状況と職場の心理社会的要因の関連性」を探索した。

B. 研究方法

石川県内の医療・介護施設 125 か所に調査用紙を送り、本調査研究の趣意に賛同を得た医療・介

護施設 95 か所及びそこで働く無作為に選定された 1 施設 20 人を対象とし、自記式質問紙調査でおこなった。

調査項目：

Ⅰ．(1) 基本属性（性別、年齢、職種、教育歴、）
(2) 生活習慣（運動、喫煙、飲酒、睡眠）
(3) 家庭環境（婚姻の有無、同居家族、介護の有無）
(4) 労働要因（雇用形態、経験年数、勤務状況、労働時間、休日日数、通勤時間）
(5) 既往歴
(6) 職場満足度

Ⅱ．腰痛の状況

Ⅲ．職業性ストレス簡易調査票

Ⅳ．STarT Back スクリーニングツール

Ⅴ．恐怖回避思考チエック表（日本語版 TSK-11-J）

Ⅵ．一般健康調査（GHQ-30）

解析方法：

解析ではそれぞれの項目ごとに欠損値のないものを有効回答数とした。分析は腰痛あり群となし群の比較には１対１のオッズ比を求めた。腰痛に関連する要因の多変量解析には多重ロジスティック回帰分析を用いた。統計分析には Stata/MP13.1 を用いた。

（倫理面への配慮）

独立行政法人労働者健康福祉機の倫理審査の承認を得て推進した．被験者に対してはデータを ID 化して管理するなど個人情報には十分配慮すること等を説明し，書面での同意を取得した。

C. 研究結果

1.回答者の背景

アンケートの回答者(施設回収率 76.0%)は 1704 人で、男性 420 人、女性 1281 人（性別未回答 3 人）であった。年齢は 10 歳代 17 人（1.0%)、20 歳代 340 人（20.0%)、30 歳代 452 人（26.5%) 40 歳代 406 人(23.8%)､50 歳代 332 人(19.5%)、60 歳代 82 人 (4.8%)、70 歳以上 1 人 (0.1%)（未回答 74 人)。教育歴は中学卒 42 人（2.5%)、高校卒 695 人（40.8%)、専門学校・高専・短大卒 746 人（43.8%)、大学卒 208 人（2.2)、大学院卒 1 名であった（未回答 12 人)。家族状況では就学前の子どもがいる者が 295 人（13.7%）にみられた。生活習慣としては、1 か月間に毎日、時々たばこを吸う人は 445 人（26.1%）に見られ、運動習慣のある者は 412 人（24.2%）であった。平均睡眠時間は 6 時間以上 7 時間未満が一番多く 660 人（38%)、次いで 5 時間以上 6 時間未満が 650 人（38%)、7 時間以上８時間未満 212 人（12%）で、5 時間未満は 125 人（7%）に見られた。雇用状況では、職種では介護福祉士が 48.0%、ホームヘルパー14.0%、看護師・保健師は 12.6%、ＰＴ／ＯＴが 1.2%、ケアワーカー6.6%である。看護・介護業務の経験年数は 10 年以上～20 年未満が 32.3%と一番多く、ついで 5 年以上～10 年未満 26.8%、2 年以上～5 年未満 17.7%、20 年以上が 11.3%、2 年未満では 10.6%で、うち 1 年以上～2 年未満 6.0%、1 年未満 4.6%であった。

2. 腰痛の状況

腰痛は、1 日以上続いた痛みで，その範囲は肋骨縁より下部で下殿溝より上部として明確に図示し、これに下肢痛を伴う場合も含むと定義した。過去 1 か月で腰痛がないと回答した人は 441 人（25.9%）で、1133 人（66.5%）の 7 割弱の人は腰痛を認めていた（以下、腰痛あり群)。腰痛がある人をさらに分析すると、腰痛を認めた人の 8 割弱 875 人（全回答者の 51.3%）は腰痛があっても仕事に支障をきたすことはないと回答していた。仕事に支障をきたしたとの回答者は 258 人(全回答者の 15.1%)にみられ､そのうちの 218 人(全回答者の 12.8%）は欠勤（休職）していないが、40 人（全回答者の 2.3%）が腰痛のため欠勤（休職）していた。さらに腰痛ありの人で腰痛を患わってから 3 か月以上経過している、つまり慢性化している人が 74.4%に見られた。また、腰痛のため、連続して 4 日以上休んだ経験のある人は 11.2%にみられた。

今までに経験した腰痛で、発症からよくなるまでにかかった時間は2週間未満が47.5%と約半数は2週間未満で軽減している。次いで2週間以上〜1か月未満が18.6%、1か月以上〜3か月未満が9.4%、3か月以上〜1年未満が6.8%で、1年以上〜3年未満は4.5%で、3年以上5.8%と1割の人が1年以上かかっていた。腰痛による医療施設への受診状況についてであるが、3割の人が整形外科を受診していて、接骨院も23.6%が受診していた。受診したことのない人も17.2%に見られた。

３．勤務状況

この1か月間における勤務状況を見てみると、早出回数は週に1回が多く24.9%に、次いで2回が22.9%に、3回は7.6%に見られる。早出がないのは21.9%であった。日勤は週に1回は18.3%、2回は13.1%、3回は13.3%にみられ、日勤がない人は18.5であった。遅出は週に1回が21.5%に、2回は21.9%に、3回は9.9%に見られ、遅出がない人は20.0%であった。

1週間の労働時間は35時間〜40時間は44.3%、41時間〜50時間が33.7%、51時間〜60時間は6.2%、61時間〜65時間1.2%、66時間〜70時間0.6%、71時間以上は1.5%いた。腰痛の有無でみてみると週に51時間以上（残業2時間以上）は腰痛あり群では9.7%、腰痛なし群では8.6%に見られ、腰痛あり群の方が多かった。

４．職場の満足度

職場の満足度では十分満足していると答えた人は11.6%、少し満足は29.5%で41.1%は満足との回答が見られているが、これに対してあまり満足していないは17.8%、全然満足していないが3.6%と21.4%は職場に満足していなかった。35.2%はどちらでもないと回答している。腰痛有無での仕事満足度であるが、満足している（十分満足している＋少し満足）は腰痛あり群で37.0%に、なし群では52.0%に認め、腰痛なし群では半数が職場に満足しているが、腰痛あり群では4割弱であった。これに対し満足していない人（あまり満足していない＋全然満足していない）は腰痛あり群23.6%、なし群15.9%であった。

５．職業ストレス調査

（1）職業性ストレス簡易調査票

職業ストレス調査としては、厚生労働省の職業性ストレス簡易調査票を用いた。このチエックリストは仕事の量的負荷3項目、仕事の質的負荷3項目、身体的負荷1項目、仕事のコントロール度3項目、技術の活用度1項目、職場の対人関係3項目、職場環境1項目、仕事の適性2項目の17項目より作成されている。今回は各下位項目4〜1点（逆転項目は1〜4点）で配点し、各項目数で除して項目の総得点を算出した。得点が高いほどストレス度が高いことになる。解析では各項目に欠損値のないものを有効回答とした。

仕事の負担は量的にも、質的にも、身体的にも負荷を感じている人は多く、各設問に65.4%〜94.1%に負担を感じると回答していた。40歳代では仕事の量的負荷を感じる人が他の年齢層に比べ多かった。身体的負荷は10歳代（100%）、20歳代（96.5%）の若い人に多かった。「高度の知識や技術が必要な難しい仕事だ」は8割が感じているが、男性（75.5%）より女性（81.3%）の方が多かった。仕事のコントロールでの負荷は3項目とも男性より女性の方が感じていた。年齢でみると、「自分のペースで仕事ができない」、「自分で仕事の順番・やり方を決めることができない」はいずれも50歳代が多く感じていた（61.4%、55.7%）。職場の仕事の方針に「自分の意見を反映でいない」と感じている者は30歳代で52.4%に認められた。対人関係では男性の方が女性より負荷を感じる人が多い。「意見の食い違いがある」は56.2%に見られるが、特に30歳代では6割にみられる。「他の部署とは馬が合わない」「職場の雰囲気が友好的でない」との回答は29.5%、25.5%にみられた。「自分の技能や知識を仕事で使うことが少ない」回答した人は24.5%に見られ、男性の方（28.1%）が女性（23.1%）よりも多かった。「職場の作業環境はよくない」との回答は

34.9%にあった。仕事への適性度・働きがいでは「自分に合っていない」と回答した人は28.9%に、特に50歳代では31.9%に見られている。「働きがいのある仕事でない」と回答は21.8%に、特に５０歳代では4人に1人（25.6%）にみられた。2項目とも男性の方が女性より回答者が多かった。

職場の支援度では、上司に「気楽に話ができない」「困った時、頼りにならない」「個人的な問題を相談したら、全く聞いてくれない」と回答しているのは6.9%、11.0%、9.9%で、同僚に対しての同じ質問ではそれぞれ1.0%、2.8%、3.5%であった。

腰痛の有無でみると、職業性ストレス簡易調査票のどの項目も腰痛あり群がなし群より高得点でストレス度が高かった。

（２）職業性ストレス簡易調査票（Ｂ項目　ストレスによっておこる心身の反応）

ストレスによる反応として心身の不調が現れるが、心身の反応についても「職業性ストレス簡易調査票」で調査した。ストレスによっておこる心身の反応は活気、イライラ感、疲労感、不安感、抑うつ感、身体愁訴に関連する全29項目から構成されている。それぞれ「ほとんどなかった」、「時々あった」、「しばしばあった」、「ほとんどいつもあった」の４段階（１～４）で採点されている。複数の項目で高得点を示した場合には、現在腰痛があろうがなかろうが、脳dysfunctionがある可能性が高いと判断できると松平はいう。

全体では「活気」が低い／少ない、やや低い／少ないと回答した人は31.0%に見られ、「イライラ感」、「疲労感」、「不安感」、「抑うつ感」、「身体愁訴」を認めた人（やや高い／多い、高い／多いと回答した）はそれぞれ29.5%、46.4%、29.0%、26.0%、26.4%にみられていた。「イライラ感」と「疲労感」は男性の方が女性より（男性36.6%：女性27.1%、男性47.6%：女性46.0%）多く、「活気」「「抑うつ感」「身体愁訴」は逆に女性の方に（男性27.7%：32.1%、男性24.5%：女性26.5%、24.8%：26.9%）多く認めていた。

腰痛の有無でみると、活気（腰痛あり群35.0%、なし群21.0%）、イライラ感（あり群32.5%、なし群24.5%）、疲労感（あり群54.7%、なし群27.7%）、不安感（あり群32.9%、なし群19.5%）、抑うつ感（あり群30.9%、なし群15.7%）、身体愁訴（あり群33.4%、なし群8.2%）が認められた。いずれも腰痛あり群がなし群よりも心身の症状の訴えが多く、疲労感は腰痛あり群ではなし群の2倍が回答していた。また抑うつ感はなし群の2倍、身体愁訴の訴えは4倍であった。

６．一般健康調査票（General Health Questionnaire 30 :GHQ-30）

一般健康調査票（GHQ）は精神健康度を測定する尺度として我が国を含め世界各国で使われている。GHQはGoldbergによって開発された精神神経症状の有無を鑑別する自記式質問紙である。総得点が高いほど精神障害である可能性が高い。GHQは本来60項目であるが、判断能力の高い項目を選んで作成された、30項目版、20項目版、12項目版がある。日本版GHQ-30はGHQ-60項目の回答結果を因子分析し、11因子を抽出して、そのうち因子性の明確な6因子すなわち「一般的疾患」、「身体的症状」、「睡眠障害」、「社会的活動障害」、「不安と気分変調」、「希死念慮・うつ傾向」を採用して、各因子の代表項目（各5項目）で構成されている。今回の調査では妥当性が高いGHQ-30を採用して精神健康度を評価した。各選択肢は「全くなかった」、「あまりなかった」、「あった」、「たびたびあった」の4肢から該当するのを1つ選んで回答するものである。採点は0点―0点―1点―1点（逆転項目あり）で採点し、総合計点を算出した。すなわち総合得点は0点～30点である。日本語版ではこれまでの研究から７／８がcut-offとされている。

GHQ-30の総合平均得点は全体で9.42±6.70点で、男性8.51±6.93点、女性9.72±6.60点で女性の方が高かった。10歳代男性が一番高得点で10.33±6.94点で、次いで20歳代女性10.27±6.47点、40歳代女性9.90±6.80点、50歳代女性

9.80±6.56 点であった。これに対し 70 歳代は 7.59±6.29 点と低得点（男性 5.67±6.98 点、女性 7.82±6.16 点）であった。

因子別に見てみると睡眠障害が一番高得点で、次いで一般的疾患傾向、身体的症状、不安と気分変調、社会的活動で希死念慮が一番低得点であった。また、社会的活動と希死念慮を除き、他の 4 因子はいずれも女性の方が男性より明らかに高得点であった。(一般的疾患傾向 1.88±1.44（男性 1.63±1.53、女性 1.96±1.41)、身体的症状 1.81±1.41（男性 1.45±1.28、女性 1.93±1.44)、睡眠障害 2.11±1.68（男性 1.90±1.69、女性 2.17±1.67)、社会的活動 1.06±1.36(男性 1.08±1.46、女性 1.05±1.36)、不安と気分変調 1.56±1.65(男性 1.42±1.62、女性 1.61±1.66)、希死念慮 1.01±1.46（男性 1.02±1.50、女性 1.00±1.45）

年齢・性別で因子を見てみると一般的疾患傾向は 50 歳代（1.98±1.44）40 歳代（1.96±1.47）が高得点で特に 40 歳代女性（2.04±1.45)、50 歳代女性（2.04±1.43)、30 代女性（2.00±1.38）が高得点であった。身体的症状は年齢では 50 歳代（1.98±1.4）が高得点で、特に 50 歳代女性は（2.07±1.46）が一番高く、次いで 40 歳代（1.86±1.41）で、40 歳代女性も（1.90±1.43）が高得点であった。睡眠障害も 50 歳代（2.31±1.74)、40 歳代（2.15±1.64）で得点が高く、特に女性が高得点（それぞれ 2.33±1.74、2.14±1.63）であった。20 歳代女性も（2.18±1.59）と高かった。社会的活動は 40 歳代で（1.16±1.46)、特に 40 歳代男性が（1.30±1.58）と高かった。不安と気分変調は 10 歳代男性が一番高得点(2.00±2.16)、次いで 20 歳代女性(1.91±1.70)40 歳代女性(1.65±1.65）が高く、20 歳代（1.76±1.71)、40 歳代（1.60±1.64）は不安と気分変調が他の年齢層に比し高い。希死念慮の得点は低いが、10 歳代(1.24±1.55、男性 1.67±2.36、女性 1.14±1.30)、20 歳代（1.20±1.55、男性 1.17±1.58、女性 1.22±1.54）につぎ 40 歳代（1.04±1.51、男性 1.01±1.50、女性 1.05±1.51）で他の年齢と比べると高い。

腰痛の有無で GHQ をみると、総合平均得点では腰痛なし群は 6.65±5.79 点、腰痛あり群では 10.85±6.68 点、要素別で比較すると一般的疾患傾向はなし群は 1.32±1.31、あり群 2.18±1.41、身体的症状ではなし群 1.26±1.20、あり群 2.11±1.38 点、睡眠障害はなし群 1.48±1.53 点、あり群 2.43±1.68 点、社会的活動ではなし群 0.81±1.29 点、あり群 1.18±1.42 点、不安と気分変調ではなし群 1.10±1.4 点、あり群 1.79±1.69 点、希死念慮ではなし群は 0.69±1.22 点、あり群 1.15±1.54 点で、総合平均得点、各要因の得点とも腰痛あり群が高得点であった。

総合得点で、7 点以上（精神健康度不良）は全体の 6 割（59.4%）にみられ、腰痛あり群では 7 割（69.5%）に、なし群では 4 割（39.5%）でみられ、腰痛あり群では明らかに精神健康状態が悪かった。

７．STarT(Subgrouping for Targeted Treatment) Back スクリーニングツール

STarT(Subgrouping for Targeted Treatment) Back スクリーニングツールは腰痛に心理社会的要因の関与が強く考えられ、標準的な整形外科的治療では改善させることは難しい心理社会的要因ハイリスク腰痛の患者さんであるかどうかを、簡便にスクリーニングするために英国で開発されたツールである。もともとは 9 設問から構成されているが、英国キール大学のグループは心理的要因に関する 5 つの設問中 4 問以上に該当した場合、心理的な要因の関与が強いハイリスク群の腰痛患者と考え、認知行動療法等を使って、早い段階で心理社会面へのアプローチを実施したほうが良いと推奨している。今回の調査ではこのツールを日本語版に訳した松平のものを使用した。判定は設問１～４で「そう思わない」、設問５で「全然」、「少し」、「中等度」と回答したのを 0 点、設問１～４で「そう思う」、設問５で「とても」、「極めて」との回答を１点として採点した。総合計点は 0 点～5 点である。

腰痛の有無にかかわらず、心理社会的要因が強く考えられる4点以上を見ると全体では10.9%の人に見られていて、男性では 8.5%に女性の11.7%に見られた。腰痛有無でみると、腰痛あり群では4点以上は173人（腰痛群の15.3%）に腰痛なし群は5人（腰痛なし群の1.1%）に見られた。

８．日本語版 TSK-11(Tampa Scale for Kinesiophobia) TSK-11-J

腰痛の痛みに対する不安感や恐怖感から過度に腰を大事にする意識や思考、活動から回避してしまう行動を恐怖回避思考（行動）と呼ぶ。この恐怖回避思考（行動）は欧米では腰痛の回復のしやすさや就労状況、慢性化に強く影響していると指摘されている。TSK は運動器に関わる分野において恐怖回避行動を測る代表的な調査票と考えられている。我々も松平らが開発・作成した日本語版 TSK-11-J を使って調査した。TSK-11-J は11問から構成されていて各設問は「少しもそう思わない」「そう思わない」を 0 点とし、「そう思う」「強く思う」をＩ点として4段階で評価している。総合計点は0点～11点で、高得点ほど恐怖回避思考（行動）が強いことになる。

腰痛の有無にかかわらず全回答者の平均得点は 2.58±2.57 点であった。腰痛の有無でみてみると腰痛あり群は 3.13±2.66 点、腰痛なし群は1.54±1.78点で腰痛群は恐怖回避思考（行動）が強かった。

９．睡眠について

睡眠時間は6時間が一番多く39%に、次が7時間で24.5%に、6割は6,7時間確保されていた。しかし 5 時間が 17.8%にみられ、5 時間未満は6.9%にみられた。腰痛の有無で睡眠時間をみてみると、5 時間未満では腰痛あり群は 7.7%、なし群では5.2%であった。

入眠に1時間以上かかる人(入眠困難)は16.0%に、途中覚醒を週に3回以上認める人(中途覚醒)は 5.9%、ほぼ毎日が 4.3%に、早朝覚醒は週 3回以上が 5.5%に、ほぼ毎日が 4.7%に見られている。起床時に疲れが取れていない人（起床時の疲労感）は週 3 回以上が 14.3%、ほぼ毎日が19.0%と3割以上の人に朝起床時に疲れが取れてないと回答している。日中の眠気は週3回以上が5.6%に、ほぼ毎日が1.8%に見られていた。腰痛の有無でみると入眠困難は腰痛あり群では18.0%、腰痛なし群は12.2%、途中覚醒は腰痛あり群 12.5%、なし群 5.7%、早朝覚醒はあり群12.4%、なし群 6.3%、起床時に疲労感が残っているのはあり群 39.9%、なし群 22.5%で腰痛あり群となし群であった。

10. 腰痛と関連する要因の検討

腰痛と各要因との関連指標として、オッズ比とその95%信頼区間を求めた(ロジスティック回帰分析)。

（１）単変量解析

職場ストレスでオッズ比が有意に高いのは、コントロール1.48、仕事の適性度・働きがい1.46、職場の支援度上司・同僚 1.30、1.27 であった。仕事の量、質、身体的、職場の環境は有意に低いオッズ比を示した。

ストレス反応では、活気以外のイライラ感、疲労感、不安感、抑うつ感、身体愁訴のオッズ比は有意に高く、それぞれ 1.16、1.30、1.23、1.11、1.19 で、特に疲労感は大きいオッズ比を示した。活気は有意に低いオッズ比を示した。

GHQ も 1.12 と有意に高いオッズ比を示した。

（２）多変量解析

職業性ストレッサーについて着目した分析として、性、年齢、仕事の量、仕事の質、身体的負荷、コントロール、対人関係、技術の活用度、職職場の環境、適性度・働きがい、支援度上司、支援度同僚を含めたモデルでオッズ比を求めると適性度・働きがいのみが有意に大きい 1.48 倍のオッズ比を示し、身体的負担で有意に小さいオッズ比を示したのみであった。

ストレス反応に着目した分析として、性、年齢、活気、イライラ感、疲労感、不安感、抑うつ感、身体愁訴を含めたモデルでオッズ比を求めると、

疲労感 1.16、身体愁訴 1.20、の大きいオッズ比を、活気と抑うつ感は小さいオッズ比を示した。

睡眠に着目した分析として、性、年齢、睡眠時間（<5 時間)、入眠困難、途中覚醒、早朝覚醒、朝の疲労感、日中の眠気を含めたモデルのオッズ比では朝の疲労感にのみ 2.28 倍の大きいオッズ比を示していた。

D. 考察

1．医療・介護施設で働く人のストレス、精神健康度

介護施設で働く人のストレスは高いと指摘されている。今回の職業性ストレスの結果と平成 23 年度に我々が行った企業での職業性ステレスの結果（平成 23 年度産業保健調査研究「職場風土から見た職場におけるメンタルヘルス対策に関する踏査研究」、回答者 1386 人）と要素別得点で比較してみると、仕事の負担度（量）介護:3.15±0.81、企業 2.98±1.38、仕事の負担度（質）介護 3.22±0.69、介護 2.97±1.23、仕事の負担度（身体的）: 介護 3.55±0.66、企業 2.34±2.16、仕事のコントロール: 介護 2.61±0.80、企業 2.41±1.33、職場の対人関係 : 介護 2.32±0.82、企業 2.22±1.34、技能の活用度 : 介護 2.11±0.69、企業 2.17±1.62、職場の環境 : 介護 2.27±0.87、企業 2.34、仕事への適性度・働きがい : 介護 2.13±0.75、企業 2.27±1.43 で、仕事の負担、仕事のコントロール、対人関係は明らかに介護職員の方が高得点で特に仕事の負担度は高かった。しかし医療・介護施設で働く人は仕事への適性度・働きがいのストレスは企業の人から見ると低かった。仕事の負担度のなかでも「体を使う仕事だ」の負担は 92.1％と多くが感じていて、ストレスによっておこる心身への反応としての疲労感も多いので体に負担のかからない介護法・仕事量、仕事時間の工夫が必要である。

介護職場では特徴的な介護者のストレスとして、暴力、ハラスメント、クレーム、いじめ、利用者へのサービス、同僚/上司との人間関係などが挙げられているが、今回は調査していないので、今後は介護者特有なストレス要因を詳細に調査する必要性があると思われる。

ストレスによっておこる心身の症状を腰痛のある人とない人で比べると、活気、イライラ感、疲労感、不安感、抑うつ感、身体愁訴いずれも腰痛あり群に症状を認める人が多く、特に疲労感、抑うつ感は腰痛あり群ではなし群の 2 倍に、身体愁訴の訴えは 4 倍に見られている。松平は心理社会的要因の強い腰痛の患者さんには、様々な身体化徴候を併せ持つケースが多く、また、松平らによる我が国の慢性疼痛実態調査（PACEsurvey）による分析で、腰痛を持っている人は腰以外の訴えもあわせ持つ人が多く、3 か所以上の部位が痛むとした人が約半数にも及んだと指摘している。そこで、今回のストレス反応の設問 19～29 身体愁訴の該当数をみると、腰痛なし群では平均 1.19 個であるが腰痛あり群は 2.97 個で、該当数 3 個以上の人は 48.7％と半数に見られ、身体徴候を有する人が多い傾向を示唆していた。

GHQ-30 では、総合得点は 9.42±6.70 点、男性 8.51±6.93 点、女性 9.72±6.60 点で平成 23 年度の企業の結果と比較すると企業では全体 8.10±13.91 点、男性 7.85±14.25 点、女性 8.41±13.48 点と明らかに介護職の方が高得点で精神健康度が悪い結果である。しかし、腰痛なし群では総合平均得点、及び各要素別得点は企業で働く人の得点より低得点であった。腰痛あり群となし群ではあり群が総合平均得点、各要素別得点とも明らかに高得点であった。Cut-off 点の 7 点以上の人は 59.4％と 6 割に見られた。腰痛あり群では 69.5％と 7 割の人で精神健康度が悪いとの結果であった。腰痛なし群では 4 割程度であった。

以上より、介護施設でのメンタルヘルス対策は重要な喫緊の課題である。

Ⅱ．腰痛に関連する要因

腰痛のあり群となし群で諸要因を比較すると、性別、年齢、運動、仕事の負荷、章句場の適性度・働きがい、支援度、ストレス反応の全ての項目（活

気、イライラ感、疲労感、不安感、抑うつ感、身体愁訴）（P＜0.01）、GHQ,得点、睡眠障害（睡眠時間と眠気は除く）でも明らかに有意差が見られた。腰痛に関連する要因を多変量解析でみると、腰痛には年齢、仕事の身体的負荷、職場への適性度・働きがいが関連しているようで、特に適性度・働きがいは高い関連が示されている。ストレス反応としての活気、疲労感、抑うつ感、身体愁訴が関連し、身体愁訴と疲労感は大きいオッズ比を示していた。腰痛とGHQ得点は関連する。

腰痛にストレスによっておこる心身の反応（活気、イライラ感、疲労感、不安感、抑うつ感、身体愁訴）やGHQ得点とは関連性が見られ、腰痛予防対策としてもメンタルヘルス対策が必要と考えられた。

Ⅲ．STarT Backと恐怖回避思考（行動）

「非特異的腰痛」つまり原因不明とされてしまう腰痛を見極める際、松平は前屈みの姿勢や持ち上げ動作をしていると腰痛を感じやすいが、歩行中は痛みはないといった場合は「脊椎dysfunction」が原因の可能性が考えられ、ストレスが強まったり、ブルーな気分になると痛みを感じやすい場合は「脳dysfunction」を介して身体化徴候としての腰痛の可能性が考えられる、としている。脳dysfunctionは、たとえば仕事への不満感や周囲のサポート不足（人間関係のストレス）といった心理社会的問題から生じる苦悩、おそれ、不安、怒りといったストレスでネガテイブな感情がトリガーとなり、その反応として心身の不調（いくつかの身体化徴候や抑うつ、強い疲労感、睡眠障害）が現れやすくなった状態で、心身の不調は、さらなる苦悩や不安を招き、脳dysfunctionはさらに強まると指摘している。

さらに、松平は「職業性ストレス簡易調査票」の「ストレスによっておこる心身の反応」のうち複数の項目で高得点を示した場合は、現在腰痛の有無にかかわらず、脳dysfunctionがある可能性が高いと判断できる可能性がある、と指摘している。また、心理社会的要因の関与が強い状態であるかどうかを、簡便にスクリーニングするツールとして「STarT(Subgroupinig for Targeted Treatment)Backスクリーニングツール」の実施を推奨している。そこで今回われわれも松平が訳したこのスクリーニングツールを用いて調査した。STarT Backスクリーニングツールは5問あり、その中で4問以上に該当した場合が心理社会的要因の関与が強いと考えられている。5設問は「痛みに対する恐怖回避思考」、「不安」、「痛みの破局的思考」、「抑うつ」、「自覚的な煩わしさ」に関する設問である。今回の結果では4問以上に該当した人は全体では10.9％に見られ、男性が8.5％、女性が11.7％と女性に多く、腰痛あり群の15.4％に見られていた。10％～15％の人が心理社会的要因の関与が予想される。腰痛者には早い段階でこのツールを用いて調査し、心理社会的要因の可能性が考えられる人達には早い段階から心理社会的アプローチへの介入が必要となる。

高齢者で転倒の際も転倒に対する恐怖や不安感から歩行を回避しているという事が見られているが、腰痛でもその痛みに対する不安感や恐怖感から過度に腰を大事にする思考や行動をとる恐怖回避思考がみられる。この恐怖回避思考が腰痛の回復経過や就労生活、慢性化に影響を及ぼすことが指摘されている。恐怖回避思考の調査票としてはFABQ(Fear-Avoidance Beliefs Questionnaire）やTSK(Tampa Scale for Kinesiophobia)が知られているが、今回は松平らが作成した日本語版TSK-11(TSK-11-J)で調査した。総合得点（0~11点）の平均得点は2.58±2.57点、腰痛あり群は3.13±2.66点、なし群は1.54±1.78点であり群で点数が高かった。得点が高いほど恐怖回避思考が強いことになる。高得点の人には認知行動療法を併用することが望ましいと考える。

今後は、本データベースを用い、遷延化した支障度の高い腰痛を従属変数とした多変量解析を行うなど、さらなる検討を行っていく予定である。

E. 結論

介護施設で働く労働者は、腰痛有訴者が多く、腰痛と職場のストレス、心身のストレス反応、および精神的健康度を含む全般的な健康との間には、明らかに負の関連があった。社会福祉法人の腰痛対策として、従来の環境整備、環境管理、腰痛運動だけでなく、職場のストレス対策・メンタルヘルス対策からの取り組みも必要であることが示唆された。

F. 健康危険情報

該当なし

G. 研究発表

1. 論文発表

なし

3. 学会発表

なし

H. 知的財産権の出願・登録状況（予定を含む）

4. 特許取得

なし

5. 実用新案登録

なし

6. その他

労災疾病臨床研究事業費補助金

分担研究報告書

腰痛に関わる実態およびリスクの同定

介護職の勤務体制と健康状況（作業支障腰痛，不眠，精神的不調）との関連性の検討

研究分担者　高井ゆかり　東京大学大学院医学系研究科健康科学・看護学専攻成人看護/緩和ケア看護学分野　（研究協力者　高橋正也 独立行政法人 労働安全衛生総合研究所）

研究要旨

介護職で健康で働けることは提供するサービスの向上につながると考えられる。本調査では，高齢者介護施設で働く介護職を対象に，労働負荷を考慮しながら，勤務体制と健康状況（作業支障腰痛および不眠と精神的不調）との関連を検討した。調査を進めるにあたり，勤務時間が長くなるにつれて，また労働負荷が高くなるにつれて，健康への望ましくない影響が現れるという仮説を設定し，介護施設（155 施設）に対して，本調査への参加を打診した。回答のあった 86 施設のうち，50 施設が参加意思を示した。参加意思を示した施設には所属する介護職の人数分の調査票を送付し，3,155 名より回答が得られた（回答率 77%）。分析の結果，労働負荷を主観評価に基づいた場合，作業支障腰痛の訴えは夜勤が長くなるにつれて増加することが分かった。それに対して，不眠と精神的不調の訴えは夜勤の長さにかかわらず，主観的労働負荷が高いと増加した。一方，労働負荷を介護職 1 名あたりの利用者数に基づいて推定した場合，夜勤が長い（16 時間以上の）時にのみ，有意な関連が認められた。労働負荷の 2 つの指標は意味するところが異なるかもしれないが，介護職の健康確保という点では，介護労働に伴う精神的・肉体的負荷を軽減することが夜勤の短縮とともに重要になると考えられた。そのためには，福祉機器の活用や，施設内で安全衛生のレベルを向上させるマネジメントシステムの確立などが求められる。

A. 研究目的

松平らの大規模全国調査によると，わが国の腰痛の生涯有病率は，8 割を超え，4 人に 1 人は、仕事等の社会活動を休んだ経験があり，腰痛は，誰でも経験しうる国民的愁訴であるといえる。加えて，厚生労働省業務上疾病発生状況等調査によると，腰痛における休業 4 日以上の業務上疾病の発生件数は，全職業性疾病の約 6 割を占め第 1 位となっている。平成 23 年の腰痛全届け出のうち社会福祉施設が 19%を占め，10 年で 2.7 倍という最も顕著な増加となった背景を踏まえ, 19 年ぶりに改訂された「職場における腰痛予防対策指針」(平成 25 年、厚生労働省)では，重症心身障害児施設等に限定されていた適用を，福祉・医療等における介護・看護作業全般に拡大し，内容を充実させるに至った。つまり，社会福祉法人等の介護の現場で活躍する介護福祉士，ケアワーカーといった介護職への腰痛対策は，産業衛生領域の喫緊の課題といえる。さらには労働負担が少なくないと想定される介護職が健康で働ける環境を提供することはサービスの向上につながると考えられる。一方，近年，腰痛と心理社会的問題に伴う精神的不調は，密接な関連があることが明らかになり，先述「職場における腰痛予防対策指針」(平成 25 年、厚生労働省)でもこの問題が指摘された。以上の背景から本調査では，高齢者介護施設で働

く介護職を対象に，労働負荷を考慮しながら，勤務スケジュールと健康状態（作業支障腰痛および不眠と精神的不調）との関連を検討した。調査を進めるにあたり，勤務時間が長くなるにつれて，また労働負荷が高くなるにつれて，健康状態への望ましくない影響が現れるという仮説を設定した。

B. 研究方法

対象

社会福祉懇談会の会員である介護施設（155 施設）に対して，本調査への参加を打診した。回答のあった 86 施設のうち，50 施設が参加意思を示した（参加拒否 5 施設，高齢者介護を行わない施設 31 施設)。参加意思を示した施設には所属する介護職の人数分の調査票を送付し（合計 4,105 名分)，配布回収を求めた。

調査項目

匿名の自記式調査票では次の項目を測定した。

勤務の状況：働く施設（特別養護老人ホーム［特養]，老人保健施設［老健］，介護療養型施設，グループホーム，その他)，この 1 ヶ月における勤務の状況（早出，日勤，遅出／準夜勤，夜勤の頻度，始業・終了時刻，担当介護職の人数，利用者の数)，主観的労働負荷（夜勤，夜勤以外)，夜勤中仮眠（頻度，長さ)，雇用形態，職種，週労働時間，仕事のストレス要因（仕事の量的負荷，裁量権，上司・同僚からの社会的支援)，現在の勤務体制に対する主観的適応度等。

健康の状況：過去 1 ヶ月の腰痛（仕事に支障をきたしたり，欠勤をしたりした腰痛を作業支障腰痛ありと定義。腰痛の範囲は，肋骨縁より下部で下殿溝より上部として明確に図示し，これに下肢痛を伴う場合も含むと定義)，睡眠（入眠困難，中途覚醒，早朝覚醒のいずれかが週に 3 回以上ある場合を不眠ありと定義，睡眠時間，起床時疲労感，昼間の強い眠気)，精神的不調（K6 で 5 点以上を不調ありと定義)，生活習慣等。

統計解析

夜勤の長さを 3 群に分けた（短:9 時間まで，中：9.1-15.9 時間，長：16 時間以上)。労働負荷は主観的評価と介護職 1 名あたりの利用者数からそれぞれ評価した。前者は 4 項目の合計得点（4～36 点）の中央値（28）で低高二分した。後者はその中央値（20）で低高二分した。これらに基づいて，6 群（短低，中低，長低，短高，中高，長高）を 2 組作成した。夜勤以外については各勤務の長さの平均値を求め，9 時間未満か以上で二分した。主観的労働負荷は中央値（26）で二分した。各勤務における介護職 1 名あたりの利用者数の平均値を求め，その中央値（8.9）で低高二分した。これらに基づいて，4 群（短低，長低，短高，長高）を 2 組作成した。夜勤あるいは夜勤以外の長さと労働負荷が作業支障腰痛，不眠，精神的不調にどのように関連するかを調べるために，短低群を参照としたロジスティック回帰分析を行った。年齢，性別，週労働時間，特養か否か（全施設の分析時のみ）による影響は統計的に調整した。また，施設による違いを検討するために，上記の分析を特養，老健，グループホーム別に行った。

（論理面への配慮）

独立行政法人労働安全衛生総合研究所の倫理審査の承認を得て推進した。被験者に対してはデータを ID 化して管理するなど個人情報には十分配慮すること等を説明し，書面での同意を取得した。

C. 研究結果

3,155 名より回答が得られた（回答率 77%)。

全施設（2,218 名）における夜勤の長さ（短中長）と主観的労働負荷の結果であるが，作業支障腰痛の訴えは労働負荷が高いと，夜勤が長くなるにつれて増加した。不眠と精神的不調の訴えは夜勤の長さにかかわらず，労働負荷が高いと増加した。この傾向は，特養のみ（1,572 名)，老健のみ（192 名）でも同様であった。グループホームのみ（239 名）では，作業支障腰痛，不眠，精神的不調の訴えはいずれも，夜勤の長さと労働負荷との関連は認められなかった。

全施設（2,262 名）における夜勤の長さ（短中長）と介護職 1 名あたりの利用者数に関する分析結果に関してであるが，作業支障腰痛の訴えは介護職1 名あたりの利用者数が高く，夜勤が長いと増加した。不眠と精神的不調の訴えについて，夜勤の長さおよび労働負荷との関連は認められなかった。特養のみ（1,607 名）でも作業支障腰痛の訴えは介護職1 名あたりの利用者数が高く，夜勤が長いと増加し，不眠の訴えについては，夜勤の長さおよび労働負荷との関連は認められなかったが，精神的不調の訴えは労働負荷が高く，夜勤が長いと増加した。老健のみ（195 名）では，作業支障腰痛，不眠，精神的不調の訴えはいずれも，夜勤の長さと介護職 1 名あたりの利用者数との関連は認められなかった。なお，夜勤が中で労働負荷が高である群は2 名であったため，分析から除外した。グループホームのみ（284 名）においては，介護職 1 名あたりの利用者数該当者が少なく各群5 名未満であったため，分析から除外した。各指標について介護職1 名あたりの利用者数が低となる群のみでみても，夜勤の長さとの関連は認められなかった。

全施設（2,832 名）での夜勤以外の長さ（短長）と主観的労働負荷に関する分析結果であるが，作業支障腰痛，不眠，精神的不調の訴えはいずれも，労働負荷にかかわらず，夜勤以外の長さが長いと増加した。この傾向は，特養のみ（1,949 名）でも同様であった。老健のみ（252 名）では，作業支障腰痛，不眠，精神的不調の訴えはいずれも，夜勤以外の長さおよび労働負荷との関連は認められなかった。グループホームのみ（288 名）では，作業支障腰痛と不眠の訴えは夜勤以外の長さが長いと増加するような傾向があったが，統計的には有意ではなかった。精神的不調の訴えは労働負荷が高く，夜勤以外の長さが長いと増加したが，結果は不安定であった。

全施設（2,734 名）における夜勤以外の長さ（短長）と介護職 1 名あたりの利用者数の分析に関してであるが，作業支障腰痛，不眠，精神的不調の訴えのいずれも，夜勤以外の長さおよび介護職1 名あたりの利用者数との関連は認められなかった。特養のみ（1,895 名）でも同様に，3 指標いずれも，夜勤以外の長さおよび介護職1 名あたりの利用者数との関連は認められなかった。老健のみ（241 名）でも，作業支障腰痛と不眠の訴えは，夜勤以外の長さおよび介護職1 名あたりの利用者数との関連は認められなかった。精神的不調の訴えについては，参照群となる夜勤以外の長さが短で介護職 1 名あたりの利用者数が低である群が 5 名未満であったため，分析から除外した。グループホームのみ（284 名）でもまた，作業支障腰痛と不眠の訴えはいずれも，夜勤以外の長さおよび介護職 1 名あたりの利用者数との関連は認められなかった。精神的不調の訴えでは，労働負荷が高く，夜勤以外の長さが長いと増加したが，結果は不安定であった。なお，夜勤以外の長さ長で介護職1 名あたりの利用者数が低である群が5 名未満であったため，分析から除外した。

D. 考察

労働負荷を主観評価に基づいた場合，作業支障腰痛の訴えは夜勤が長くなるにつれて増加することが分かった。それに対して，不眠と精神的不調の訴えは夜勤の長さにかかわらず，主観的労働負荷が高いと増加した。一方，労働負荷を介護職 1 名あたりの利用者数に基づいて推定した場合，夜勤が長い（16 時間以上の）時にのみ，有意な関連が認められた。労働負荷の2 つの指標は意味するところが異なるかもしれないが，介護職の健康確保という点では，介護労働に伴う精神的・肉体的負荷を軽減することが夜勤の短縮とともに重要になると考えられた。そのためには，福祉機器の活用や，施設内で安全衛生のレベルを向上させるマネジメントシステムの確立などが求められる。それらを通じて，介護職の健康のみならず，介護の質的改善や介護職の離職防止も期待できる。早出，日勤，遅出／準夜勤など夜勤以外の勤務では，労働負荷よりむしろ，勤務時間の長さが

カギになるように思われた。従って，夜勤以外であっても，勤務時間の不必要な延長には注意が必要と言える。

施設の型ごとに調べると，勤務時間および労働負荷と腰痛，不眠，精神的不調との関連は特養，老健，グループホームによって異なることが示唆された。本調査では特養で働く介護職が大半であり，それ以外の施設で働く介護職の人数は少なかった。この人数の問題は大きく関わっている可能性はある。また，対象となった施設の介護度という面では，特養 3.9±SD 0.3，老健 3.3±0.3，グループホーム 2.8±0.4 と各群の間で有意差もあった（P<0.05）。従って，各施設の介護業務の特徴に即して勤務条件を適正に調整することが肝要と考えられた。

E. 結論

高齢者介護施設で働く介護職を対象に，勤務体制と健康状況（作業支障腰痛および不眠と精神的不調）との関連を検討した結果，作業支障腰痛の訴えは夜勤が長くなるにつれて増加した。不眠と精神的不調の訴えは夜勤の長さにかかわらず，主観的労働負荷が高いと増加した。

F. 健康危険情報

該当なし

G. 研究発表

1. 論文発表

- Takai, Y., Yamamoto-Mitani, N., Abe Y. & Suzuki, M. Literature review of pain management for people with chronic pain, Japan Journal of Nursing Science, Article first published online: 19 NOV 2014 | DOI: 10.1111/jjns.12065
- Takai, Y., Yamamoto-Mitani, N., Kawakami, S., Abe, Y., Kamiyama, M. & Saito, S. Differences between Nurses' and Care workers' Estimations of Pain Prevalence among Elderly Residents, Pain Management Nursing, 16 (1): 20-32, 2015.
- Takai, Y., Abe, A., Torimoto-Sasai, Y., Okamoto, Y., Kamiyama, M. & Yamamoto-Mitani, N. Compliance of urinary continence care for Japanese residents on short-stay respite services, International Journal of Urological Nursing, 8(2):90-96, 2014.
- Takai, Y., Yamamoto-Mitani, N., & Ko, A. Prevalence of and factors related to pain among elderly Japanese residents in long-term healthcare facilities, Geriatrics & Gerontology International, 14(2):481-9, 2014
- Takai, Y., Yamamoto-Mitani, N., Ko, A., & Heilemann, M.V. Differences in pain measures by Mini-Mental State Examination scores of residents in aged care facilities: Examining the usability of the Abbey Pain Scale- Japanese version, Pain Management Nursing, 15(1): 236-245, 2014.
- Takai, Y., Yamamoto-Mitani, N., Chiba, Y., & Kato, A. Feasibility and clinical utility of the Japanese Version of the Abbey Pain Scale in Japanese aged care, Pain Management Nursing, 15(2): 439-448, 2014.
- 鈴木みずえ，古田良江，高井ゆかり，佐藤文美，大城一，山本則子，金森雅夫，認知症高齢者における疼痛の有症率と疼痛が認知症の行動・心理症状（BPSD）に及ぼす影響，老年看護学，19(1)：25-33，2014
- 古田良江，鈴木みずえ，高井ゆかり，在宅高齢者の痛みと健康関連 QOL の関連と痛み緩和対策の実態，日本早期認知症学会誌 7(2)：26-35，2014
- 鈴木 みずえ，山本 則子，高井 ゆかり，古田良江，鈴木 有希，金森 雅夫：認知症高齢者の痛みに関するアセスメントツールとケア介入，日本早期認知症学会誌，7(1)：53-58，2014
- 古田良江，鈴木みずえ，高井ゆかり，在宅虚弱高齢者である二次予防事業参加者の疼痛有症率と疼痛の状況が健康関連 QOL に及ぼす影響，老年看護学，18(2)：48-57，2014.

２．学会発表

- Takai Y & Yamamoto-Mitani N:A feasibility study of developed chronic pain management standards for older residents，第 34 回日本看護科学学会学術集会，名古屋，2014 年 11 月
- 高井ゆかり，古田良江，阿部吉樹，鈴木みずえ，交流集会「高齢者の慢性痛へのセルフケアを支える看護」，第 34 回日本看護科学学会学術集会，名古屋，2014 年 11 月
- Takai Y, Yamamoto-Mitani N,: A qualitative study of expectations and attitudes toward doctors/therapists among elderly Japanese patients with chronic pain, 14th World Congress on Pain (International Association for the Study of Pain: IASP), Buenos Aires, Argentina, 2014 年 10 月
- 高井ゆかり，山本則子，認知症高齢者を在宅で介護する家族員が介護サービスを決定・利用す

る際のパターン，日本家族看護学会第 21 回学術集会，倉敷市，2014 年 8 月

- 古田良江，鈴木みずえ，高井ゆかり，二次予防事業参加者の疼痛緩和対策の実態，日本老年看護学会第 19 回学術集会，名古屋，2014 年 6 月
- 高井ゆかり，山本則子，千葉いくみ，体の痛みと共に老いを生きる 慢性痛のある高齢者の経験の探索，日本老年看護学会第 19 回学術集会，名古屋，2014 年 6 月
- 山本則子，高井ゆかり，鈴木美穂，五十嵐歩，竹原君江，長期療養施設におけるケアの質向上の取り組みに関する文献レビュー，日本老年看護学会第 19 回学術集会，名古屋，2014 年 6 月

H. 知的財産権の出願・登録状況（予定を含む）

7. 特許取得

なし

8. 実用新案登録

なし

9. その他

労災疾病臨床研究事業費補助金

分担研究報告書

腰痛に関わる実態およびリスクの同定

仕事に支障をきたす腰痛が遷延化する因子の検討

研究分担者　三好光太　労働者健康福祉機構 横浜労災病院 整形外科 脊椎脊髄外科

研究要旨

欧米の研究では，心理社会的要因が非特異的腰痛の遷延化に影響することが明らかになって久しいが，日本においての検証は乏しい。当該分野の今後の両立支援に役立てる情報として，仕事に支障をきたす腰痛の遷延化に関わる危険因子を探索的に検討した。看護師を含む労働者を対象に，前向きに追跡したコホート研究である JOB (Japan epidemiological research of Occupation-related Back pain) study の１年間の追跡データを解析に用いた。ベースライン時，仕事に支障のある腰痛を直近１ヶ月に経験した労働者が，１年間のフォローアップ期間に同等の腰痛を３ヶ月以上経験していた場合を遷延化と定義し，遷延化する因子をロジスティック回帰分析で検討した。ベースライン時に回答した 5,310 名中，3,811 名が 1 年フォローアップに回答した（追跡率：71.8%）。171 名にベースラインでの直近 1 カ月に仕事に支障のある腰痛があり，そのうち 46%が，看護・介護あるいは 20kg 以上の重量物を取り扱う作業に従事していた。171 名中 29 名（17.0%）がフォローアップ期間中，遷延化していた。ロジスティック回帰分析の結果，働きがい（オッズ比 3.62，95%信頼区間 1.17 - 11.2)，不安感（オッズ比 2.89，95%信頼区間 0.97 - 8.57，および仕事や生活の満足度（オッズ比 4.14，９５%信頼区間 1.18-14.58）が，他要因を調整しても遷延化の危険因子として挙げられた．仕事に支障をきたす腰痛の遷延化による職場における労働力の損失を予防するための今後の対策として，職場の心理社会的要因へのアプローチも重要視する必要があると思われた。

A.研究目的

腰痛は慢性化しやすい性質を持つ最もポピュラーな痛み愁訴であり，その多くが原因疾患の特定しきれない非特異的腰痛に分類される。最近の我が国の現状でも，慢性疼痛を有する部位では，腰部が最も有病率が高い。作業関連性疾患の代表格でもあり，米国においては多くの人が腰痛を抱えながら仕事をしているものの，腰痛に対する医療費の 75%以上は 5%の支障度の強い患者に費やされているともされており，Snook は現代社会において大きな問題は，“low back pain” ではなく，“low back disability (LBD)”であると述べている。つまり，産業現場では単なる腰痛ではなく作業に影響する支障度の高い腰痛の危険因子を明らかにし，予防対策を講じる必要がある。

西欧では，非特異的腰痛に関し画像上の異常所見が痛みの起源や予後を基本的には説明できない事実及び人間工学的アプローチのみでは腰痛対策が立ち行かない背景もあり，非特異的腰痛の危険因子として心理社会的要因も重要視されるようになった。一方，我が国での産業衛生的アプローチは，画像所見を参考にしつつ人間工学的問題を主に対策を講じているのが現状であり，心理社会的要因にも十分配慮したしたうえで危険因子を探る目的の前向き研究もほとんど行われてこなかった。そこで本邦勤労者の「仕事に支障をきたす非特異的腰痛」の危険因子について心理社会的要因を含む多因子の中から探索することを

主目的とし，JOB（Japan epidemiological research of Occupation-related Back pain）study を実施した。今回は，看護師を含む JOB study のデータベースから，当該分野の今後の両立支援に役立てる情報として，LBD 慢性（遷延）化に関わる危険因子を探索的に検討した。

B. 研究方法

JOB study では，腰痛およびそれに関連しうる多要因（多くの個人的要因，人間工学的要因，心理社会的要因等）を網羅した自己記入式調査票を作成し，郵送法により実施することとした。腰痛の範囲は，肋骨縁より下部で下殿溝より上部として明確に図示し，これに下肢痛を伴う場合も含むと定義した。

また，仕事への支障度によって腰痛の程度を，Von Korff らの grading を参照に，4 段階で評価した。このうち，grade 2 と 3 を仕事に支障をきたす支障度の強い腰痛（LBD）とした。以下，具体的な grade の定義を示す。

Grade 0:腰痛を伴うことはなかった

Grade 1:腰痛を伴うことはあったが，仕事に支障をきたすことはなかった

Grade 2:腰痛のため仕事に支障をきたしたこともあったが，休職はしなかった

Grade 3:腰痛のため休職をした

心理社会的要因に関する質問票としては，厚生労働省の職業性ストレス簡易調査票を用いた。

主に首都圏の 4 労働者健康福祉労災病院（看護師）を含む 16 事業所の勤労者 6,140 名（18 歳以上）に前向き調査を依頼，ベースラインの調査では 5310 人から回答を得て（回収率 86%）翌 1 年の腰痛状況（前述の grade）等の追跡調査を行った。そのうちベースライン（調査時直近の 1 ヶ月）に LBD があった者を抽出し，翌 1 年間に同等の LBD を 3 ヶ月以上経験したこと，つまり LBD が遷延化したこと（従属変数）の危険因子をベースライン時に収集した変数を用い探索した。なお，追跡した 1 年間に腰痛以外の理由で業務内容に変更のあった人，交通外傷で腰痛になった人，骨折等特異的な疾患で腰痛を伴った人は解析するにあたり除外した。

独立変数は，ベースライン時の個人的要因として年齢（40 代未満/40 代/50 代以上），性別，肥満（Body Mass Index：BMI 25kg/㎡以上を肥満ありと定義），喫煙習慣（Brinkmann 係数 400 以上をヘビースモーカーと定義），学歴（最終学歴を中学・高校卒等と大学・短大・専門学校等で区分），平均睡眠時間（5 時間未満を短睡眠時間と定義），運動習慣(過去 1 年間の定期的な運動習慣の有無)，腰痛体操習慣の有無，前屈の柔軟性（指先が足首に届かない場合を柔軟性が乏しいと定義），通院が必要な併存症の有無，生活習慣病の有無，腰痛既往の有無，作業の経験年数（5 年未満か以上か），人間工学的（身体への負荷）要因として，前屈動作，捻り動作，持ち上げ動作，物を押す動作（それぞれ 1 日作業時間おいて半分以上行っているか否か），重量物取り扱い作業（取り扱いなし（主にデスクワーク）/取り扱い 20kg 未満/20kg 以上あるいは介護作業）とした。

心理社会的要因としては，前述した職業性ストレス簡易調査票から算出した 19 因子（心理的な仕事の負担，職場での対人関係でのストレス，仕事のコントロール度，働きがい，疲労感，不安感，抑うつ感，上司及び同僚からのサポート等）の 5 段階評価の結果を 2 群に分けた評価（例：「仕事の量的負担」は，1-3 段階（少ない/やや少ない/普通）と 4-5 段階（やや多い/多い）の 2 群）に加え，単調な反復作業と感じているか否か，勤務形態（日中の勤務か夜勤のある不規則な交代制か），仕事時間（週 60 時間未満か以上か），雇用形態（正社員か否か），職場での腰痛対策の有無，小児期（14 歳以下）の心的外傷歴があり現在もそれが影響しているか否か，生活や仕事に支障をきたす腰痛の家族歴の有無とした。

統計解析についてはロジスティック回帰分析によりオッズ比を求め，危険因子の評価指標とした．単変量解析により粗オッズ比と 95%信頼区間

を求めた後，統計的に有意な関連を認めた要因から多重共線性と解釈可能性を考慮して選択したものを独立変数として多変量解析を行ない，要因調整オッズ比（性・年齢でも調整）とその95%信頼区間を算出した。統計的検定は両側で行い，有意水準は 5%とした。統計パッケージは STATA 9.0（StataCorp, LP, College Station, TX)を用いた。

（倫理面への配慮）

独立行政法人労働者健康福祉機の倫理審査の承認を得て推進した. 被験者に対してはデータをID化して管理するなど個人情報には十分配慮すること等を説明し，書面での同意を取得した。

C. 研究結果

ベースライン時に回答した参加者 5,310 名中，3,811 名が 1 年フォローアップに回答した（追跡率:71.8%)。平均年齢 42.9 歳（標準偏差 10.1)，男性が 80.6%を占めた。追跡できなかった集団と，年齢，性別，BMI は，近似しており統計学的有意差はなかった。

171 名（平均年齢 41.5 歳，標準偏差 10.2，男性 71.4%，平均 BMI 23.0 kg/m2）がベースラインでの直近 1 カ月に LBD をもっており，そのうち 79 名（46.2%）が，看護・介護あるいは 20kg 以上の重量物を取り扱う作業に従事していた。

171 名中 29 名（17.0%）がフォローアップ期間中，３ヶ月以上の LBD（仕事に支障のある腰痛）を経験していた。

ロジスティック回帰分析の結果，働きがい（オッズ比 3.62，95%信頼区間 1.17‐11.2， p＝0.025)，不安感（オッズ比 2.89，95%信頼区間 0.97‐8.57， p＝0.056，および仕事や生活の満足度(オッズ比 4.14，９５%信頼区間 1.18-14.58，p＝0.027）が，他要因を調整しても LBD 遷延化の危険因子として挙げられた。

D. 考察

LBD が慢性(遷延)化に影響する要因は，仕事や生活での満足度が低い，働きがいが乏しい，不安感が強いといった、職場を主とする心理社会的要因であることが，今回の検討から示唆された。本知見は，欧米のエビデンスと矛盾しない。

メカニズムとしては，心理社会的要因がストレッサーとなり，中脳辺縁系ドパミン・オピオイドシステムの機能異常に続発する下行性疼痛調節系や自律神経系のアンバランスに伴う中枢性感作（痛覚過敏）や局所の血流低下・筋攣縮などが考えられる。

我が国の産業衛生分野において，人間工学的なアプローチによる腰痛の予防や対策が主流であった。しかしながら，厚生労働省業務上疾病発生状況等調査にて、腰痛における休業 4 日以上の業務上疾病の発生件数は，長年にわたり全職業性疾病の約 6 割を占め第 1 位であり，近年の世界疾病負担研究においても 289 の疾患や傷病のうち，腰痛が Years Lived with Disability（YLDs)のトップにランクているなど，我が国においてもグローバルにも労働現場での LBD は減少していない。言い換えれば，従来の対策が奏功しているとは言い難い。

今後は，LBD 遷延化による職場における労働力の損失を予防・緩和するための今後の対策として，心理社会的要因へのアプローチも重要視する必要があると思われる。

結果の一般化には限界があるが，職業そのものではなく，作業形態を調整したことにより，この結果が介護・看護作業はもちろんのこと，他の業種についても参考にしてよい知見であると思われる。

E. 結論

仕事に支障をきたす非特異的腰痛が遷延することの危険因子は，仕事や生活での満足度が低い，働きがいが乏しい，不安感が強いといった、職場を主とする心理社会的要因であることが示唆された。

F. 健康危険情報

該当なし

G. 研究発表

1. 論文発表

1) Matsudaira K, Kawaguchi M, Isomura T, Inuzuka K, Koga T, Miyoshi K, Konishi H. Assessment of psychosocial risk factors for the development of non-specific chronic disabling low back pain in Japanese workers- Findings from the Japan epidemiological research of Occupation-related Back pain (JOB) study. (Ind Health, 2015, in press)
2) Matsudaira K, Isomura T, Miyoshi K, Okazaki H, Konishi H. Risk factors for low back pain and katakori: a new concept. Nihon Rinsho. 2014; 72:244-50. Japanese

4. 学会発表

なし

H. 知的財産権の出願・登録状況（予定を含む）

10. 特許取得

なし

11. 実用新案登録

なし

12. その他

I. 参考文献

1) Garg A, Moore JS. Epidemiology of low-back pain in industry. Occup Med 1992; 7:593-608.
2) Krismer M, van Tulder M. Low back pain (non-specific). Best Practice & Research Clinical Rheumatology 2007; 21: 77-91.
3) Deyo RA, Rainville J, Kent DL. What can the history and physical examination tell us about low back pain? JAMA 1992; 268: 760-765.
4) Nakamura M, Nishiwaki Y, Ushida T, et al. Prevalence and characteristics of chronic musculoskeletal pain in Japan. J Orthop Sci 2011; 16: 424-32.
5) 松平浩，竹下克志，久野木順一，他．日本における慢性疼痛の実態-Pain Associated Cross-Sectional Epidemiological(PACE) survey 2009. JP-. ペインクリニック 2011; 32: 1345-56.
6) Frymoyer JW, Cats-Baril WL. An overview of the incidences and costs of low back pain. Orthop Clin North Am 1991; 22: 263-71.
7) Snook SH. Work-related low back pain: secondary intervention. J Electromyogr Kinesiol. 2004; 14: 153-60.
8) Chou R, Fu R, Carrino JA, Deyo RA. Imaging strategies for low-back pain: systematic review and meta-analysis. Lancet 2009; 373: 463-72.
9) Manek NJ, MacGregor AJ. Epidemiology of back disorders: prevalence, risk factors and prognosis. Curr Opin Rheumatol 2005; 17: 134-40.
10) Hoogendoorn WE, van Poppel MN, Bongers PM, Koes BW, Bouter LM. Systematic review of psychosocial factors at work and private life as risk factors for back pain. Spine 2000; 25: 2114-25.
11) Waddell G and Burton AK. Occupational health guidelines for management of low back pain at work: evidence review. Occup Med 2001; 51: 124-35.
12) van Tulder M, Koes B, Bombardier C. Low back pain. Best Pract Res Clin Rheumoatol 2002; 16: 761-75.
13) Von Korff M, Ormel J, Keefe FJ, et al. Grading the severity of chronic pain. Pain 1992; 50: 133-149.
14) 下光輝一, 小田切優子: 職業性ストレス簡易調査票.産業精神保健 2004; 12: 25-36.
15) Akaha H, Matsudaira K, Takeshita K, et.al. Modified measurement of finger-floor distance –Self assessment bending scale-. J lumbar Spine Disord 2008; 14: 164-69.
16) Pincus T, Burton K, Vogel S, et al. A systematic review of psychological factors as predictors of chronicity/disability in prospective cohorts of low back pain. Spine 2002 ; 27: E109-120.
17) Leknes S, Tracey I: A common neurobiology for pain and pleasure. Nature Reviews Neuroscience 2008; 9: 314-20.
18) Schults W. Getting formal with dopamine and reward. Neuron 2002; 36:241-263.
19) Wood PB. Mesolimbic dopaminergic mechanisms and pain control. Pain 2006; 120: 230-34.
20) 松平浩．職場での腰痛には心理・社会的要因も関与している－職場における非特異的腰痛の対策－．産業医学ジャーナル 2010; 33: 60-66.

労災疾病臨床研究事業費補助金

平成 26 年度研究報告書

予防に有用な福祉機器等の開発

健常若年成人を対象とした腰部負担を軽減する体幹装具の開発と評価

研究分担者　勝平純司　国際医療福祉大学小田原保健医療学部

研究要旨

従来の体幹装具は装着することで体幹運動を制限することで腰部負担の軽減を目指している．しかしながら，先行研究では体幹装具装着による腰部負担の軽減効果を示すことができていない．また，体幹装具は長期間装着すると体幹周囲筋，特に側腹筋の弱化につながると指摘されている．そこで我々は継手の抗力により胸部を前方から押す力を与えることで腹筋の活動を促通し，背筋の活動を低減する新しい体幹装具 Trunk solution（以下 TS）を開発し，Good Design 賞を受賞した．本研究では健常若年成人を対象とし，TS の歩行における脊柱起立筋の活動に対する効果と外した後の持ち越し効果および TS 装着時の側腹筋の筋厚を従来の体幹装具の中で最も多く用いられているダーメンコルセットと比較することを目的とした．結果として，TS を装着することにより，歩行時の脊柱起立筋の活動が減少するとともに外した直後においてもその効果が維持された．また，TS を装着することにより，体幹深部筋である腹横筋の筋厚が増加した．上記の効果はダーメンコルセットを装着しても認められなかった．脊柱起立筋の過活動は腰痛につながり，体幹深部筋のエクササイズは腰痛予防に効果があると報告されている．TS を装着することによる脊柱起立筋の活動を低減しながら，腹横筋の収縮を促通する効果は腰痛予防に効果があると考えられる．今後は腰痛有訴者を対象に同様の効果が得られるかを検証していく必要がある．

A.研究目的

従来の体幹装具は，その効果として過剰な体幹運動の制限・腹圧増強・体幹筋活動量の減少などによる腰部負担の軽減などが推察されている．しかし，この効果に関しては否定的な報告も多く，Poppel らの系統学的レビューでは，客観的な計測値を用いた多くの先行研究では体幹装具による腰部負担軽減効果を示すことが出来ていないと報告している．また，先行研究において，脊柱起立筋の過活動が腰痛の一因であり，脊柱起立筋の筋活動を低下させることが重要であると報告されている．しかしながら，従来の体幹装具を装着しても脊柱起立筋の活動を減少させることはできないと報告されている．加えて，従来の体幹装具は長期間装着することで体幹周囲筋が弱化してしまうという問題点も指摘されている．Rostami らは体幹装具を 4 週間連続装着すると外腹斜筋，内腹斜筋，腹横筋の側腹筋の筋厚が減少することを報告している．

これらから，勝平らは，体幹支持体と骨盤支持体を抗力を具備した継手により連結した体幹装具 Trunk Solution(以下 TS)を新たに開発し，2014 年度の Good Design 賞を受賞した．TS は装着した際に継手の抗力によって体幹を伸展方向に押す力を与えて腹筋群の活動を高め，脊柱起立筋の活動を低下させることを目的としており，健常成人では歩行時の腹筋群の活動を高め，脊柱起立筋の筋活動を低下させることや骨盤の前傾を促すこ

とが報告されている．しかしながら，TS による腰部負担軽減効果に関して外した後の持ち越し効果の検証や体幹深部筋を含む側腹筋に対する効果の検証も行われていない．

そこで，我々は基礎研究として，若年健常成人を対象に 1)TS 装着時および外した後の歩行時の脊柱起立筋の筋活動を従来の体幹装具であるダーメンコルセットと比較すること，2)TS とダーメンコルセット装着時の側腹筋厚を比較検証することを目的とし，本研究を実施した．

B. 研究方法

1)歩行時の脊柱起立筋の計測

対象は健常成人男性 24 名(年齢 22.0±1.6 歳，身長 171.4±4.cm，体重 62.6±7.3kg)とした．なお，対象は整形外科疾患や中枢神経疾患を有さない者とした．被検者は，TS 装着群(以下:TS 群)(年齢 22.4±1.9 歳，身長 171.5±6.0cm，体重 63.5±9.2kg)とダーメンコルセット装着群(以下：ダーメン群)(年齢 21.5±1.5 歳，身長 171.3±5.2cm，体重 61.8±6.7kg)の 2 群にランダムに選別した．

歩行解析機器として，Gait Judge System（パシフィックサプライ社製）を用いた．Gait Judge System とは，wifi コンバータと wifi を受信する専用アプリをダウンロードした iPad からなり，iPad にリアルタイムに動画や筋活動等が記録される．筋活動の計測には，サンプリング周波数 1000Hz の表面筋電計(パシフィックサプライ社製)を使用した．記録用電極はメッツ社製 Ambu Blue Sensor P を使用し，先行研究に従い，被験者の皮膚処理を施した後に双極性表面電極 2 個を電極中心間隔 3 ㎝で貼付した．筋活動の測定筋は，右側の脊柱起立筋とした．

計測課題は歩行とした．被験者は計測室内に設けられた約 10m の直線歩行路を自由速度にて歩行を行った．被験者をランダムに TS 群，ダーメン群に分け，歩行は同一被験者に対して①装具装着前，②装具装着時，③外した直後の計 3 条件で計測を行った．計測プロトコールとして，装具装着前に歩行計測後，装具を装着し 5 分間安静後に計測を実施， TS を外して 5 分間安静後に計測を実施した．歩行計測実施後，各筋の最大随意収縮(Maximal Voluntary Contraction：MVC)の筋活動を測定し，歩行時の筋活動を正規化するために用いた．

2) 側腹筋の計測

対象は体幹，下肢に神経学的・整形外科的な既往のない健常男性 27 名（平均年齢 22±2.3 歳，平均身長 170.0±0.5 ㎝，平均体重 61.5±6.5 ㎏ BMI21.0±1.8）とした．なお全対象者は事前に本研究の目的と方法を説明した．

側腹筋の測定には超音波画像診断装置 Sonosite（FUJIFILM 社製）を用いた．再現性を得るためにプローブは右側の前腋窩線上にて肋骨辺縁と腸骨稜の中央部にあてるようにして腹横筋を測定した．計測は，非装着時,TS 装着時，ダーメンコルセット装着時の計 3 回をランダムに測定した．

上記二つの研究は，国際医療福祉大学の倫理委員会の承認を得て実施した．また，対象者全員に対して，本研究の目的と内容を十分に説明し，書面による同意を得た後に計測を行った．

C. 研究結果

1)歩行時の脊柱起立筋の計測

脊柱起立筋に関しては，1 歩行周期において TS 装着前と比較して TS 装着時に有意に減少した．また，TS 装着前と比較して TS を外した直後でも有意に減少した．遊脚期において TS 装着前と比較して TS 装着時に有意に減少した．ダーメン群では，1 歩行周期・各歩行周期において有意差は認められなかった．

2) 側腹筋の計測

腹横筋では，装具なしに比べ TS 装着時に有意な筋厚の増加が認められた．さらにダーメンコルセット装着時より TS 装着時にも有意な筋厚の増加が認められた．しかし，装具なしとダーメンコルセット装着時の間には有意差は認められなか

った．内腹斜筋では，安静時の装具なし，ダーメンコルセット装着時，TS 装着時には有意差は認められなかった．外腹斜筋では，装具なしに比べ TS 装着時に有意な筋厚の増加が認められた．しかし，装具なしとダーメンコルセット装着時の間，ダーメンコルセット装着時と TS 装着時の間には有意差は認められなかった．

D. 考察

1)歩行時の脊柱起立筋の計測

脊柱起立筋は，1 歩行周期において，TS 装着前と比較して TS 装着時，TS を外した直後に有意に減少した．これにより，TS の腰部負担軽減効果が持ち越し効果として発揮されることが明らかになった．先行研究において，勝平らは，健常成人における TS 装着時の歩行時の腹直筋と脊柱起立筋の 1 歩行周期における筋活動分析を行っており，腹直筋が有意に増大し，脊柱起立筋が有意に減少すると報告している．本研究においても，TS 装着時は脊柱起立筋が有意に減少しており，先行研究を支持する結果となった．また，新たな結果として，TS を外した直後においても脊柱起立筋が有意に減少した．TS 装着により腹筋群の筋活動が賦活された結果，TS を外した直後においても脊柱起立筋の筋活動が減少したと考えられる．

また，遊脚期において TS 装着時に有意に減少した．脊柱起立筋の歩行時の活動パターンに関して，両脚支持期において筋活動が増大することが報告されており，また，中村らは，歩行周期全般にわたって活動がみられると報告している．本研究では遊脚期において筋活動が減少する結果となった．先行研究において，TS 装着時における単脚支持期では腹直筋が有意に増大すると報告されている．遊脚期は左側の単脚支持期にあたり，単脚支持期において腹筋群の筋活動が賦活された結果，体幹の安定性が向上し，脊柱起立筋の筋活動が減少したと考えられる．

2）側腹筋の計測

超音波画像診断装置を用いて TS 装着時と非装着時の側腹筋厚を測定し，各条件による筋厚変化について検討した．研究結果から，TS を装着することで腹横筋の筋厚が有意に増加することが明らかとなった．このことは，TS が腹横筋に対する促通効果を持ち，TS 装着自体が効果的に腹横筋を収縮させるエクササイズとなる可能性を示している．腹横筋は呼吸筋の１つであり，腹横筋による胸腰筋膜の緊張は，脊椎の安定性に寄与すると考えられている．Urquhart らの報告によると腹横筋は体幹の最深部に位置する筋で体幹の安定性に重要な役割があり，腹横筋は胸郭の固定に働くという作用があるとの報告がある．この作用機序より，TS が継手の抗力によって胸部を前方から押す力を与えることで，静止した状態で体幹直立姿勢を維持するために脊柱の安定に働く腹横筋の収縮が促され，結果として TS 装着時に腹横筋が収縮したことが考えられる．また，先行研究より腰椎と骨盤の後傾位よりも中間位や前傾位の方が腹横筋に良好な特定の反応が得られたという報告がある．我々の予備研究により TS は歩行時だけでなく，立位時にも骨盤の前傾を促すことが明らかになっていることから，立位時に骨盤の前傾を促す TS の効果が腹横筋の筋活動を優位にさせたのではないかと考えられる．

その他にも腹横筋のような体幹深部筋は腰椎分節間および骨盤の分節を細かく調節するように機能するといわれている．腰部負担について Hodges らは，腰痛の原因は腹横筋の活動が低下し，体幹の分節運動のコントロールが破綻することによって引き起こされることが多いと報告している．コルセットの使用は外から締め付けることで腹横筋が本来持つ脊柱を安定させる作用を代償していると考えられ，Rostami らが報告しているように長期間使用することで腹横筋の弱化につながると考えられる．一方，TS を使用すると自らの腹横筋により体幹を保持できる可能性があるため，新たな腰痛を治療する手法として用いることができる可能性がある．

E. 結論

TS を装着した歩行は脊柱起立筋の活動を減少させるとともに，外した直後においてもその効果が持続することがわかった. TS を装着することで体幹側腹筋のうち，腹横筋と外腹斜筋の筋厚が増大することが明らかとなった. 腰背部の筋である脊柱起立筋の活動を減少させ，体幹深部筋である腹横筋の筋厚を増大させる TS の効果は腰痛の予防や治療に対して有効であると考えられる.

F. 健康危険情報

該当なし

G. 研究発表

1. 論文発表

1. 勝平純司，福祉支援工学の基礎（体幹装具 Trunk Solution）. Biophilia 3: 26-30, 2014
2. Hasegawa T, Katsuhira J, Matsudaira K, Iwakiri K, Maruyama H. Biomechanical Analysis of Low Back Load when Sneezing. Gait Posture 40: 670-675,2014
3. 伊藤晃洋,勝平純司,飯島進乃,地域在住高齢者の静止立位における足圧中心位置に影響を与える変数の検討-装具を用いた体幹への介入効果を含めて -，臨床バイオメカニクス 35：357-361, 2014

2. 学会発表

H. 知的財産権の出願・登録状況（予定を含む）

13. 特許取得

なし

14. 実用新案登録

なし

15. その他

労災疾病臨床研究事業費補助金

平成 25 年度研究報告書

介護看護従事者への予防介入とマネジメントシステムの構築に関する研究

研究分担者　岡敬之　東京大学医学部附属病院　22 世紀医療センター　運動器疼痛メディカルリサーチ＆マネジメント講座

研究要旨

厚生労働省業務上疾病発生状況等調査にて、腰痛における休業 4 日以上の業務上疾病の発生件数は、全職業性疾病の約 6 割を占め第 1 位となっている。平成 23 年の腰痛全届け出のうち社会福祉施設が 19%を占め、10 年で 2.7 倍という最も顕著な増加となった背景を踏まえ、19 年ぶりに改訂された「職場における腰痛予防対策指針」(平成 25 年、厚生労働省)では、重症心身障害児施設等に限定されていた適用を、福祉・医療等における介護・看護作業全般に拡大し、内容を充実させるに至った。つまり、介護・看護従事者への腰痛対策は、産業衛生領域の喫緊の課題といえる。また世界疾病負担研究にて 289 の疾患や傷病のうち、腰痛が Years Lived with Disability (YLDs)のトップにランクされるなど、社会的損失や健康面への影響の大きい腰痛への対策は global にも重要な課題として位置づけられている。

本研究では、産業衛生領域の喫緊の課題である腰痛対策を効率的に行うために、簡易で即実践できる体操に加え、産業理学療法士からの科学的根拠に基づいた教育の有益性に大規模介入比較試験を行い、エビデンスを構築する。具体的には、全国 12 労災病院をクラスターとして、A:対照（無介入)、B : 腰椎伸展体操の普及・実践、C:B+産業理学療法士による腰痛教育・相談の実践の 3 群,各群約 1,500 例、総計 4,500 例の無作為比較試験を行う。 また、介入における非改善に関しても検討（危険因子の抽出）を予定している。

A.研究目的

厚生労働省業務上疾病発生状況等調査にて、腰痛における休業 4 日以上の業務上疾病の発生件数は、全職業性疾病の約 6 割を占め第 1 位となっている。平成 23 年の腰痛全届け出のうち社会福祉施設が 19%を占め、10 年で 2.7 倍という最も顕著な増加となった背景を踏まえ、19 年ぶりに改訂された「職場における腰痛予防対策指針」(平成 25 年、厚生労働省)では、重症心身障害児施設等に限定されていた適用を、福祉・医療等における介護・看護作業全般に拡大し、内容を充実させるに至った。つまり、介護・看護従事者への腰痛対策は、産業衛生領域の喫緊の課題といえる。また世界疾病負担研究にて 289 の疾患や傷病のうち、腰痛が Years Lived with Disability (YLDs)のトップにランクされるなど、社会的損失や健康面への影響の大きい腰痛への対策は global にも重要な課題として位置づけられている。

本研究では、産業衛生領域の喫緊の課題である腰痛対策を効率的に行うために、簡易で即実践できる体操に加え、産業理学療法士からの科学的根拠に基づいた教育の有益性に大規模介入比較試験を行い、エビデンスを構築する。研究初年となる本年度は研究実施に必須となるプロトコール

を確定する。

B. 研究方法

国 12 労災病院をクラスターとして、A:対照（無介入）、B：腰椎伸展体操の普及・実践、C:B+産業理学療法士による腰痛教育・相談の実践の 3 群を実施するため、統計学的な見地を踏まえデザインを行い、以下のプロトコールを作成した

（論理面への配慮）

本研究は、研究対象者の組み入れ前であるが、同意取得やデータは匿名化の方法は確立しており、研究遂行にあたり倫理面での問題はないとの承認を、全国労災病院倫理委員会より得ている。

C. 研究結果

研究プロトコールは以下の通りである。

1. 施設をクラスターとした無作為比較試験
2. 対照（無介入)、腰椎伸展体操の普及・実践、B の介入+産業理学療法士による腰痛教育・相談の実践の 3 群
3. 北海道中央（予定看護師数：155)、東北（421)、関東（610)、横浜（585)、新潟（261)、浜松（236)、旭（189)、大阪（662)、関西（619)、中国（363)、愛媛（180)、長崎（300)、総計 4,581 名。以上 12 労災病院（施設）のをクラスターとし、病床・看護師数、看護師の男女数・平均年齢を割付調整因子とし、コンピューターの乱数表を用い、3 群（4 施設ごと）に無作為割付する非盲検試験

4.エンドポイント：EQ-5D と腰痛に関わる医療施設での治療日数から概算した医療費から算出した QALY、腰痛の有無および仕事への支障度を勘案した腰痛 grade（重症度）の改善、直近 4 週の腰痛の程度（Numerical Rating Scale)、腰痛の自覚的改善度、腰痛予防対策の自覚的実行度、腰痛の受診状況、腰痛に対する恐怖回避思考（FABQ 身体)、Kneel Start Back スクリーニングシステムによるリスク、抑うつ（K6)、過去 30 日間の仕事のでき具合（HPQ)、労災病院検診データ

[介入期間：1 年]

5. 選択基準:選定された労災病院に勤務する成人（20 歳以上）看護師、本研究の趣旨に賛同し同意を得た者

除外基準：妊婦，あるいは妊娠の疑いがある場合、腰椎伸展により症状が誘発される腰部脊柱管狭窄症と診断されたことがある者、研究の同意を撤回した者

6. サンプルサイズ計算の根拠：本研究の目的は、簡易で即実践できる体操に加え、産業理学療法士からの科学的根拠に基づいた教育の有益性に大規模介入比較試験を行うことにより、エビデンスの構築を行うことであるが、先行研究では介入にも関わらず改善に至っていない例が散見される。このため、介入における非改善に関しても検討（危険因子の抽出）を予定している。介入後の非改善をイベントにしてロジスティック回帰分析を行った場合、説明変数は最大 17 項目を見込んでおり、1 説明変数について最低 50 症例が必要という観点に基づき、非改善者数 400、これを先行研究における非改善率　57.1 %から算出すると、１群は 1,500 例となる。これが 3 群となるため，最低 4,500 例の登録が必要となる。また本研究は施設をクラスターとした無作為化を行うために、各施設での原則全例参加が必要となる。このため全国労災病院の職員数、年齢を考慮に入れて参加施設を選出したところ 4,581 名という数字が必要十分な条件であることが分かった。以上に基づき、サンプルサイズの設計を行った。

D. 考察

産業衛生領域の喫緊の課題である腰痛対策を効率的に行うために、簡易で即実践できる体操に加え、産業理学療法士からの科学的根拠に基づいた教育の有益性に大規模介入比較試験を行い、エビデンスを構築ために、統計学的な見地を踏まえデザインを行い、プロトコールを完成した

E. 結論

研究プロトコールが完成し、試験実施に向けての調整が進行している。

F. 健康危険情報

該当なし

G. 研究発表

1. 論文発表

1. Yamada K, Matsudaira K, Takeshita K, Oka H, Hara N, Takagi Y. Prevalence of low back pain as the primary pain site and factors associated with low health-related quality of life in a large Japanese population: a pain-associated cross sectional epidemiological survey. Mod Rheumatol 24: 343-348, 2014
2. Muraki S, Akune T, En-yo Y, Yoshida M, Tanaka S, Kawaguchi H, Nakamura K, Oka H, Yoshimura N. Association of dietary intake with joint space narrowing and osteophytosis at the knee in Japanese men and women: The ROAD Study. ***Mod Rheumatol*** 24, 236-242, 2014
3. Muraki S, Akune T, Nagata K, Ishimoto Y, Yoshida M, Tokimura F, Tanaka S, Oka H, Kawaguchi H, Nakamura K, Yoshimura N. Association of knee osteoarthritis with onset and resolution of pain and physical functional disability: The ROAD study. ***Mod Rheumatol*** 24:966-973, 2014
4. Hashizume H, Yoshimura N, Nagata K, Miyazaki N, Ishimoto Y, Nishiyama R, Oka H, Yamada H, Yoshida M: Development and evaluation of a video exercise program for locomotive syndrome in the elderly. ***Mod Rheumatol*** 24, 250-257, 2014
5. Yoshimura N, Nagata K, Muraki S, Oka H, Yoshida M, Enyo Y, Kagotani R, Hashizume H, Yamada H, Ishimoto Y, Teraguchi M, Tanaka S, Kawaguchi H, Toyama Y, Nakamura K, Akune T: Prevalence and progression of the radiographic ossification of posterior longitudinal ligament and its associated factors in the Japanese populations: A 3-year follow-up of the ROAD study. ***Osteoporos Int*** 25, 1089-1098, 2014
6. Akune T, Muraki S, Oka H, Tanaka S, Kawaguchi H, Tokimura F, Yoshida H, Suzuki T, Nakamura K, Yoshimura N: Incidence of certified needed care in the long-term care insurance system and its risk factors in the elderly of Japanese population-based cohorts: the ROAD study. ***Geriatrics & Gerontology International*** 14, 695-701, 2014
7. Akune T, Muraki S, Oka H, Tanaka S, Kawaguchi H, Tokimura F, Yoshida H, Suzuki T, Nakamura K, Yoshimura N. Association of physical activities of daily living with the incidence of certified need of care in the long-term care insurance system of Japan: the ROAD study. ***J Orthop Sci*** 19:489-496, 2014
8. Akune T, Muraki S, Oka H, Tanaka S, Kawaguchi H, Nakamura K, Yoshimura N. Exercise habits during middle age are associated with lower prevalence of sarcopenia: the ROAD study. ***Osteoporos Int*** 25:1081-1088, 2014
9. Yamada K, Matsudaira K, Takeshita K, Oka H, Hara N, Takagi Y: Prevalence of low back pain as the primary pain site and factors associated with low health-related quality of life in a large Japanese population: a pain-associated cross-sectional epidemiological survey. ***Mod Rheumatol*** 24, 343-348, 2014
10. Teraguchi M, Yoshimura N, Hashizume H, Muraki S, Yamada H, Minamide A, Oka H, Ishimoto Y, Nagata K, Kagotani R, Takiguchi N, Akune T, Kawaguchi H, Nakamura K, Yoshida M. Prevalence and distribution of intervertebral disc degeneration over the entire spine in a population-based cohort: the Wakayama Spine Study. ***Osteoarthritis Cartilage*** 22:104-110, 2014
11. Teraguchi M, Yoshimura N, Hashizume H, Muraki S, Yamada H, Oka H, Minamide A, Nakagawa H, Ishimoto Y, Nagata K, Kagotani R, Tanaka S, Kawaguchi H, Nakamura K, Akune T, Yoshida M. The association of combination of disc degeneration, endplate signal change, and Schmorl node with low back pain in a large population study: the Wakayama Spine Study. ***Spine J*** pii: S1529-9430(14)01758-6. doi: 10.1016/j.spinee.2014.11.012, 2014
12. Nagata K, Yoshimura N, Hashizume H, Muraki S, Ishimoto Y, Yamada H, Takiguchi N, Nakagawa Y, Minamide A, Oka H, Kawaguchi H, Nakamura K, Akune T, Yoshida M. The prevalence of cervical myelopathy among subjects with narrow

cervical spinal canal in a population-based magnetic resonance imaging study: the Wakayama Spine Study. ***Spine J*** 14:2811-2817, 2014

13. Yoshimura N, Akune T, Fujiwara S, Shimizu Y, Yoshida H, Omori G, Sudo A, Nishiwaki Y, Yoshida M, Shimokata H, Suzuki T, Muraki S, Oka H, Nakamura K. Prevalence of knee pain, lumbar pain and its coexistence in Japanese men and women: The Longitudinal Cohorts of Motor System Organ (LOCOMO) study. ***J Bone Miner Metab*** 32:524-532, 2014
14. Ohya J, Miyoshi K, Oka H, Matsudaira K, Fukushima M, Nagata K. Optimal measurement for "posterolateral protrusion" of the vertebral artery at the craniovertebral junction using computed tomography angiography. ***J Craniovertebr Junction Spine*** 5:151-156, 2014
15. Ito H, Takatori Y, Moro T, Oshima H, Oka H, Tanaka S. Total Hip Arthroplasty After Rotational Acetabular Osteotomy. ***J Arthroplasty*** 2014 Oct 8. pii: S0883-5403(14)00746-3. doi: 10.1016/j.arth.2014.10.002, 2014
16. Ogihara S, Yamazaki T, Maruyama T, Oka H, Miyoshi K, Azuma S, Yamada T, Murakami M, Kawamura N, Hara N, Terayama S, Morii J, Kato S, Tanaka S. Prospective multicenter surveillance and risk factor analysis of deep surgical site infection after posterior thoracic and/or lumbar spinal surgery in adults. ***J Orthop Sci*** 20:71-77, 2015
17. Ohya J, Oshima Y, Takeshita K, Oka H, Chikuda H, Taniguchi Y, Matsubayashi Y, Tanaka S. Patient satisfaction with double-door laminoplasty for cervical compression myelopathy . ***J Orthop Sci*** 20: 64-70, 2015
18. Muraki S, Akune T, En-Yo Y, Yoshida M, Suzuki T, Yoshida H, Ishibashi H,Tokimura F, Yamamoto S, Tanaka S, Nakamura K, Kawaguchi H, Oka H, Yoshimura N. Joint space narrowing, body mass index, and knee pain: the ROAD study (OAC1839R1). ***Osteoarthritis Cartilage*** 2015 Jan 30. pii: S1063-4584(15)00024-2. doi: 10.1016/j.joca.2015.01.011, 2015
19. Yoshimura N, Akune T, Fujiwara S, Shimizu Y, Yoshida H, Nishiwaki Y, Sudo A,Omori G, Yoshida M, Shimokata H, Suzuki T, Muraki S, Oka H, Nakamura K. Incidence of disability and its associated factors in Japanese men and women: the Longitudinal Cohorts of Motor System Organ (LOCOMO) study. ***J Bone Miner Metab***, in press
20. Muraki S, Akune T, Nagata K, Ishimoto Y, Yoshida M, Tokimura F, Tanaka S, Kawaguchi H, Nakamura K, Oka H, Yoshimura N. Does osteophytosis at the knee predict health-related quality of life decline? A 3-year follow-up of the ROAD study. ***Clin Rheumatol*** , in press
21. Yoshimura N, Muraki S, Oka H, Nakamura K, Kawaguchi H, Tanaka S, Akune T. Serum levels of 25-hydroxyvitamin D and the occurrence of musculoskeletal diseases: a 3-year follow-up to the road study. ***Osteoporos Int***, in press
22. Kagotani R, Yoshida M, Muraki S, Oka H, Hashizume H, Yamada H, Enyo Y, Nagata K, Ishimoto Y, Teraguchi M, Tanaka S, Nakamura K, Kawaguchi H, Akune T, Yoshimura N. Prevalence of diffuse idiopathic skeletal hyperostosis (DISH) of the whole spine and its association with lumbar spondylosis and knee osteoarthritis: the ROAD study. ***J Bone Miner Metab***, in press
23. Nakamura M, Hashizume H, Oka H, Okada M, Takakura R, Hisari A, Yoshida M, Utsunomiya H. Physical Performance Measures Associated With Locomotive Syndrome in Middle-Aged and Older Japanese Women. ***J Geriatr Phys Ther***, in press
24. Yamada H, Terada M, Iwasaki H, Endo T, Okada M, Nakao S, Hashizume H, Minamide A, Nakagawa Y, Nishi H, Tsutsui S, Oka H, Yoshida M. Improved accuracy of diagnosis of lumbar intra and/or extra-foraminal stenosis by use of three-dimensional MR imaging: comparison with conventional MR imaging. ***J Orthop Sci***, in press

2. 学会発表

1. Yoshimura N, Muraki S, Oka H, Tanaka S, Kawaguchi H, Nakamura K, Akune T: Mutual associations among diseases causing disability, such as musculoskeletal diseases, metabolic syndrome components, and mild cognitive impairment: A 3-year follow-up of the ROAD study. **European Credit Transfer and Accumulation System**

(ECTS) 2014**, Prague, 2014.5.17-20

2. Yoshimura N, Muraki S, Oka H, Tanaka S, Kawaguchi H, Nakamura K, Akune T: Mutual associations among musculoskeletal diseases, metabolic syndrome, and cognitive impairment: A 3-year follow-up of the ROAD study. **The European League Against Rheumatism (EULAR) 2014**, Paris, France, 2014.6.11-14
3. Muraki S, Akune T, Tanaka S, Kawaguchi H, Nakamura K, Oka H, Yoshimura N: Dose Osteophytosis at the Knee Predict Health-related Quality of Life Decline? A 3-Years follow-up of the ROAD Study. **The European League Against Rheumatism (EULAR) 2014**, Paris, France, 2014.6.11-14
4. Oka H, Ohashi S, Kadono Y, Yasui T, Ono K, Isawa K, Yoshimura N, Nishino J, Tanaka S: Assessment of joint destruction at the knee in rheumatoid arthritis using semi-automated software for Magnetic resonance image analysis. **The European League Against Rheumatism (EULAR) 2014**, Paris, France, 2014.6.11-14
5. Yoshimura N, Muraki S, Oka H, Tanaka S, Kawaguchi H, Nakamura K, Akune T: Mutual associations among diseases causing disability, such as musculoskeletal diseases, metabolic syndrome components, and mild cognitive impairment: A 3-year follow-up of the population-based cohort ROAD. **IOF Regionals 5th Asia-Pacific Osteoporosis Meeting**, Taipei, Chinese Taipei, 2014.11.14-16
6. Kodama R, Oka H, Muraki S, Tanaka S, Nakamura K, Akune T, Yoshimura N: Prevalence of Hand Osteoarthritis in the General Japanese Population: The ROAD Study. **IOF Regionals 5th Asia-Pacific Osteoporosis Meeting**, Taipei, Chinese Taipei, 2014.11.14-16
7. Muraki S, Akune T, Tanaka S, Kawaguchi H, Nakamura K, Oka H, Yoshimura N: Effect of Osteophytosis at the Knee on Health-related Quality of Life. A 3-Year Follow-up of the ROAD Study. **IOF Regionals 5th Asia-Pacific Osteoporosis Meeting**, Taipei, Chinese Taipei, 2014.11.14-16
8. Muraki S, Akune T, Oka H, Tanaka S, Kawaguchi H, Nakamura K, Yoshimura N: Muscle strength rather than muscle mass of the lower limb is associated with knee pain: The ROAD study. **World Congress on Osteoporosis,Osteoarthritis and Musculoskeletal Diseases (WCO-IOF-ESCEO)2015,** Milan, Italy, 2015.3.26-29

H. 知的財産権の出願・登録状況（予定を含む）

16. 特許取得

なし

17. 実用新案登録

なし

18. その他

労災疾病臨床研究事業費補助金
平成 26 年度研究報告書

個人と職場の双方に有益な腰痛治療と職業生活との両立支援手法の開発

腰痛予防を目的としたメール指導の課題

研究分担者　野村卓生　関西福祉科学大学保健医療学部リハビリテーション学科

研究要旨

平成 25 年度サービス産業強化事業費補助金（地域ヘルスケア構築推進事業費補助金）の助成を受けて行われた課題名「いつでもフィジカルコンサルティング」（Physical Consultant 研究，以下，「PCo 研究」という）のデータベースを利用し，まず，相談者（勤労者）の事例を供覧し，メールによる腰痛予防指導のあり方やその効果を考察する．ついで，指導者（理学療法士）へのアンケート結果から，インターネットや携帯端末機器を利用した効果的なメール指導を行う上での基礎資料を得ることを目的とした．PCo 研究および事例分析から，メール指導は相談者の腰痛予防のための行動変容を促すのに効果的であるが，腰痛予防のための行動変容段階は後退するので，継続的な指導介入が必要であり，この継続的指導によって望ましい行動が維持されると考える．本研究によって，腰痛予防を目的とした行動変容を促すためには，どのようなタイミングで何回の指導が必要かまでには言及できないが，1 名の指導者が同時期に 5 名の勤労者の腰痛予防相談を受けて回答することができると思われた．腰痛予防以外にも，その他の運動器の症状，生活習慣や家族の介護の相談があり，これに対応できる職種として理学療法士のニーズが高いと考える．

A. 研究目的

（研究背景）

2008 年（平成 20 年）4 月より，内臓脂肪型肥満に着目した特定健康診査・特定保健指導（以下，「特定健診・保健指導」という）の実施が医療保険者に義務付けられた[1)]．特定健診・保健指導では，検査結果・質問票の結果を踏まえ，対象者個々のリスクの程度に応じて「動機付け支援」，「積極的支援」に分類され，それぞれに応じた特定保健指導が行われる．積極的支援の支援形態では，個別，グループ，電話，電子メール（電子メール・FAX・手紙等）のいずれか，もしくは組み合わせて行うこととされ，対象者の行動変容を促すにあたってメール支援（指導）の利用が推奨されている．

身体活動の分野においても，特定健診・保健指導が開始される前から，携帯電話のメールを活用した身体活動支援の取り組み[2)]や，最近では職域におけるウォーキングプログラムへの電子メールの活用[3)]などが試みられている．我々も健常若年者を対象にした運動継続への携帯電話メールの指導効果[4)]や健常高齢者を対象にして携帯電話メール等を利用した遠隔地からの身体活動支援への指導効果[5)]について，短期的な身体活動向上への効果を実証している．インターネットや携帯端末機器経由での身体活動

介入研究をレビューした報告では，短期間の介入成功率は50%程度であるとされており[6]，携帯電話やインターネットの更なる普及，より活用しやすいソフトウェアの開発によって，この成功率は今後向上する可能性がある．しかしながら，インターネットや携帯端末機器経由での身体活動介入に関する長期的効果を評価できている研究は少なく，長期的な影響については，効果的な介入の方法論のあり方をふまえて，今後の検討課題である．以上，長期的な介入の効果については今後の検討課題であるが，インターネットや携帯端末機器経由での身体活動介入については，短期間の成功確率は50%以上と考えられ，現在の特定保健指導にも取り入れられる「人の行動変容を促すのに効果的なツール」であると思われる．

一方，業務上疾病の約6割を占める腰痛については，最近，心理・社会的要因も関与していることが明らかにされ，正しい情報の提供や周囲の励ます態度などは腰痛を軽快させることが明らかになっている[7]．腰痛予防に関しても，特定健診・保健指導で用いられるメール指導による腰痛予防効果の有効性が考えられるが，十分な検討はなされていなかった．そこで，我々は非特異的腰痛を有する勤労者を対象として，メール指導による腰痛予防への効果を検証するに至った．

（メール指導による腰痛予防効果の検証）

我々は，平成25年度サービス産業強化事業費補助金（地域ヘルスケア構築推進事業費補助金）の助成を受けて，課題名「いつでもフィジカルコンサルティング」（<u>P</u>hysical <u>Co</u>nsultant研究，以下，「PCo研究」という）を行った[8]．PCo研究とは，前述した研究背景の下，産業保健分野における理学療法士介入を目指し，勤労者の腰痛予防を目的としたメール指導効果の検証とこれによる理学療法士活用の新しい事業のモデル化を示した研究である．PCo研究では，新日鉄住金ソリューションズ株式会社（東京都中央区），NTN株式会社（大阪府大阪市）に勤務する事務系勤労者20名を対象として，臨床経験3年以上の理学療法士20名が個別対応し，メールを用いた腰痛予防の指導にあたることとした．メール指導を始める前に腰痛予防の基本コンセプト[9]を統一することとした．この基本コンセプトの統一にあたっては，相応の経験を有する理学療法士が主導してコンセプトの共有化に努めた．メール相談の実施頻度としては，理学療法士からの送信による一方向性の連絡を基準として，初回，2週間後，1ヵ月後，その後は月に1回のペースとした．PTからの定期連絡の最低送信回数は8回，メール指導の介入期間は6ヵ月間である．理学療法士からの定期的なメール送信以外にも対象者から相談があった場合には対応することとした．メール相談の内容は，腰痛の対処方法に関する相談以外にも回答することに統一とした．

クラウドシステムを用いて，指導者が担当の対象者から相談される内容を共有し，指導内容については，腰痛予防指導について相応の経験を有する理学療法士2名が各指導者へ寄せられる対象者らの相談内容・指導内容を確認し，指導者が対象者からの相談内容に苦慮する場合に個別対応した．研究事務局は関西労災病院治療就労両立支援センターとし，本研究に対しての質問に

応じることとした．対象には口頭と文書で説明を行い，研究協力への同意を得た．知り得た個人情報については研究事務局で一括管理し，対象者側も指導者側も個人情報を知り得ないように双方は仮名でやり取りすることとした．

結果，メール指導前後において労働者が各自の職務をどれほど上手にできているかを表す指標である Work Ability Index（WAI）[10]の有意な向上，腰痛に対する恐怖回避の思考を表す Fear-Avoidance Beliefs Questionnaire（FABQ）[11]の改善傾向を認め，理学療法士による腰痛予防を目的としたメール指導の一定の効果を認めることを報告した[12]．

（本研究で何をどこまで明らかにするか）

本研究においては，我々が行った PCo 研究のデータベースを用い，まず，特徴的であった相談者の事例を供覧し，メール指導のあり方やその効果を考察する．

ついで，指導者（理学療法士）へのアンケート結果から，インターネットや携帯端末機器を利用した効果的なメール指導を行う上での基礎資料を得ることを目的とした．

B. 研究方法

PCo 研究のデータベースを用い，まず，相談者（勤労者）からの 6 ヵ月にわたる腰痛予防に関連する相談内容と行動変容に関する事例の概要を供覧する．

ついで，指導者（理学療法士）にアンケート調査を行うこととした．尚，指導者は臨床経験 3 年以上で現職を有する理学療法士である．アンケート項目は，1）相談者の個人情報の必要性，2）指導者が相談者に返信するまでの期間，3）相談者からの返信に対して指導者が回答文章の作成に要する時間，4）相談者が指導者に返信したメールの回数，5）指導者が考える相談者からの相談対して返信内容を考える理想的な時間，6）腰痛以外の相談内容，7）指導者が考える 1 ヵ月に対応可能な相談者の人数，8）指導者が考える PCo 研究での問題点とした．

C. 研究結果

（事例紹介）

- 趣味：スポーツ（サッカー，フットサル，マラソン，スキー）
- 初回から 2 週後の相談内容と行動変容：腰部と臀部側面にときおり痛み有り．ストレッチやラジオ体操を行うようになった．
- 2 ヵ月後から 4 ヵ月後の相談内容と行動変容：寒くなってきたので腰の状態に注意している．ストレッチやラジオ体操をさぼったら，一気に体が硬くなりなった．今週から，また真面目にストレッチとラジオ体操に取り組んでいる．スポーツも結果を気にせず楽しみながら行いたいと思っている．
- 5 ヵ月後から 6 ヵ月後の相談内容と行動変容：足のストレッチも教えて欲しい．足のストレッチもやってみる．
- 相談回数について：この事例では，指導者から相談者へのメール送信回数は 18 回，相談者から指導者への返信回数は 14 回であった．

（指導者へのアンケート調査結果）

1） 相談者の個人情報の必要性について：全ての指導者が相談者の個人情報が必要

と回答した．

2) 指導者が相談者に返信するまでの期間について:相談者から返信があった際に，指導者が返信までにかかる期間の平均は，2.0±0.4 日であった．
3) 相談者からの返信に対して指導者が回答文章の作成に要する時間について:指導者が回答の文章を作成するのに要した時間の平均は，22.0±9.7 分であった．
4) 相談者が指導者に返信したメールの回数について:相談者が指導者へ返信したメール回数の平均は 4.7±4.2 回であった．
5) 指導者が考える相談者からの相談に対して返信内容を考える理想的な時間について:指導者が考える理想的な時間の平均は，20.3±13.7 分であった．
6) 腰痛以外の相談内容について：肩凝り・肩の痛み：2 件，冷え性：1 件，朝起きた際のこわばり：1 件，家族の介護：1 件，肥満：1 件，運動不足：1 件，下肢の痛み：1 件あった．
7) 指導者が考える 1 ヵ月に対応可能な相談者の人数について:現所属を有する指導者が 1 ヵ月に対応可能な相談者の人数の平均は，5.3±7.4 名であった．
8) 指導者が考える PCo 研究での問題点と今後の改善策について:複数に認めた意見として，事前に対象者の情報が欲しい：4 件，メール自体を確認してもらったかどうかが不明である：2 件，メール指導のガイドラインや具体例が必要である：2 件，返信がない場合の指導者の対処方法を決めて欲しい：2 件があった．その他の意見として，相手方が必要としている情報を提供できているのか不明：1 件，指導に対する効果の判定が難しい：1 件，指導者によって差がでた場合，相談者の不満に繋がる可能性がある：1 件，返信のない相談者に対する対応に迷う，相手の質問に対してどこまで踏み込むべきか不明である：1 件，匿名であるので相談者と信頼関係を築くのが難しい：1 件，定量的な相談者と指導者が共通認識できるデータやツールが欲しい：1 件あった．

D. 考察

（事例からみたメール指導のあり方と効果）

今回の腰痛予防の指導においては，基本コンセプトを統一した上で，臨床経験 3 年以上の理学療法士が指導者としてメールでの指導を行った．

供覧した事例においては，比較的，指導者からのメールを確認・返信され，また相談者自らも質問をされていた．この相談者は，腰部と臀部側面にときおり痛みを訴えられており，その予防・軽減への対応として，指導者は身体活動を勧め，結果，職場で行われる毎朝のラジオ体操やストレッチを行うといった行動変容が認められている．2 ヵ月後には，行動変容段階の後退を認めるも，指導者の継続的な指導によって，一旦中断していたラジオ体操やストレッチに取り組むようになり，行動変容段階の進展が認められた．また，趣味のスポーツで腰痛が悪化しないように気を付けるといった考え方の変化も認められた．コンプライアンスの高まりとともに，5 ヵ月後には，下肢のストレッチも教えて欲しいといった，自主的に考え，体をケアしていくといった

行動変容が認められた．

供覧した事例では，指導後に望ましい行動への変容が認められるが，行動変容段階の後退も認められた．治療としての体系的な教育を受けた糖尿病患者においては，基本治療へ取り組む度合いは，薬物療法で90%以上，食事療法で 60%，運動療法で 40～60%と運動療法の継続は最も難しい [13)]．健康日本 21 の最終評価結果 [14)]をみても，身体活動の必要性や重要性が色々な手段で啓発されている中，日常生活における歩数は減少しており，身体活動の維持・向上は極めて難しいことは明らかである．身体活動の維持・向上には，継続的な指導介入が必要不可欠であり，この継続的な指導介入によって，行動変容を促進させ，望ましい行動を維持させる可能性が高いと考える．

（指導者へのアンケート調査結果からみたメール指導のあり方と問題点）

今回，研究の方法論上，個人情報の保護の観点から，研究終了後にも指導者は相談者を特定できない，相談者は指導者を特定できないという点に配慮して，双方にマスキングを行った．これについては，全ての指導者から個人情報の必要であるとの回答を得たが，今後の展開も鑑み（例えばスマートフォンのアプリ化をした場合など），不特定多数からの相談でも対応できるような指導方法のマニュアル化が必要と考えられた．もちろん，例えば企業との契約となった際などは，企業の同意や個人の同意を得たうえで，相談者の個人情報を指導者に提供することも可能であるが，逆に相談者への指導者の個人情報の提供に関しても検討することが必要と考えられた．

指導者が考える相談者からの相談に対して返信内容を考える理想的な時間の平均は 20.3±13.7 分，実際に返信までに要した時間は 22.0±9.7 分であり，理想的な時間通りに返信できていたことが伺えた．指導者が返信までに要した期間の平均は 2.0±0.4 日であり，円滑に返信ができていたと想定される．1 ヵ月に何名の相談者を担当できるかについては平均で 5.3±7.4 名と幅が大きいが，現職を有する今回の理学療法士で 100 名程度の相談者へのメール指導は同期間に可能と考えられた．

当初より予想はされていたが，腰痛以外の相談もあり，その概要は運動器の症状から，生活習慣の問題や家族の介護の問題まで幅広かった．これら医療・介護の問題に対応するには，解剖学や生理学など医学的な知識を有し，リハビリテーションの領域に精通している理学療法士でなければ難しいと思われ，産業保健分野においても理学療法士のニーズは高いと思われた．

最後に，今回の「腰痛予防を主眼に置いたメール指導」をツールとして，産業保健分野への理学療法士の参入（事業化）を考えるにあたっては，指導にかかる料金設定，理学療法士の指導によって万が一不測の事態が行った場合の補償，多数のデータを管理するためのデータベース・システムの構築の必要性，より簡便に使用可能なシステムの開発，企業との契約などの多くの問題がある．また，費用対効果を如何にして示し，事業者や勤労者に理学療法士介入の有効性を理解して頂くかなど，解決しなければならない問題は多い．

E. 結論

1. メール指導は相談者の腰痛予防のための行動変容を促すのに効果的と考える.
2. 腰痛予防のための行動変容段階は後退するので, 継続的な指導介入が必要であり, この継続的指導によって望ましい行動が維持されると考える.
3. 効果的な指導回数には言及できないが, 本研究によって 1 名の指導者が同時期に 5 名の勤労者の腰痛予防相談を受けて回答することができると思われる.
4. 腰痛予防以外にも, その他の運動器の症状, 生活習慣や家族の介護の相談があり, これに対応できる職種として理学療法士のニーズが高いと考える.

F. 研究発表

論文発表

1. Takuo Nomura, Katayama Kunihiro, Kashiwa Tomoyuki, Akezaki Yoshiteru, Sato Atushi: Maintenance of the rate of stair use over a long-term period using a stair climbing campaign. Journal of Occupational Health 56(6): 511-518, 2014.
2. 野村卓生: 理学療法領域における身体活動研究の動向. 運動疫学研究 16(2): 76-82, 2014.

学会発表

1. 高野賢一郎, 浅田史成, 野村卓生, 明崎禎輝, 山縣英久: フィジカルコンサルティングによる腰痛予防・改善の試み. 日本職業・災害医学会会誌 62: 増別 167, 2014.
2. 浅田史成, 野村卓生, 高野賢一郎: 職場における身体活動指導の進め方 理学療法士の立場から. 日本衛生学雑誌 69: S170, 2014.

G. 知的財産権の出願・登録状況

1. 特許取得

   なし
2. 実用新案登録

   なし
3. その他

   なし

引用文献

1. 厚生労働省: 検診・保健指導のあり方, 特定健診・特定保健指導について. http://www.mhlw.go.jp/stf/seisakunitsuite/bunya/kenkou_iryou/kenkou/seikatsu/（2015 年 2 月 17 日閲覧）
2. 久保田晃生: 地域健康福祉への具体的アプローチ･運動習慣者をいかに増やすか IT を活用した生活習慣改善支援プログラム(i-exer:アイエクサ)の展開. 体力科学 54: 21-24, 2005.
3. 須藤英彦, 濱崎絹子, 原田和弘, 他: 電子メールを活用した職域ウォーキングプログラムの開発と評価. 日本健康教育学会誌 22: 133-145, 2014.
4. 冨田豊, 野村卓生, 佐藤厚: 携帯電話メール機能を利用した運動介入効果について 青年期における運動介入の試み. 高知女子大学紀要 56: 35-39, 2007.
5. Nomura T, Akezaki Y, Tomita Y, et al: Promoting Exercise in Elderly Japanese People with Motivational Signs: Does Short-term Intervention Influence Exercise Habits and HQOL? Journal of Rehabilitation and Health Sciences 6: 5-10, 2008.
6. 山津幸司, 熊谷秋三: Information Communication Technology を活用した身体活動介入プログラムに関する研究. 健康科学 32: 31-38, 2010.
7. 松平浩: 職場での腰痛には心理・社会的要因も関与している 職場における非特異的腰痛の対策. 産業医学ジャーナル 33: 60-66, 2010.
8. 一般社団法人産業理学療法研究会: いつでもどこでもフィジカルコンサルティング成果報告書. 平成 25 年度サービス産業強化事業費補助金（地域ヘルスケア構築推進事業費補助金）, 平成 26 年 2 月.
9. 松平浩: 新しい腰痛対策 Q&A 21 非特異的腰痛のニューコンセプトと職域での予防法, 産業医学振興財団, 2012.
10. Tuomi K, Ilmarinen J, Jahkola A, et al. Work Ability Index. Helsinki,

Finland: Finnish Institute of Occupational Health: 3-18, 1994.
11. 松平浩，犬塚恭子，菊池徳昌，他：日本版 Fear-Avoidance Beliefs Quetionnaire (FABQ-J)の開発 言語的妥当性を担保した翻訳版の作成. 整形外科 62: 1301-1306, 2011.
12. 高野賢一郎, 浅田史成, 野村卓生, 他: フィジカルコンサルティングによる腰痛予防・改善の試み. 日本職業・災害医学会会誌 62: 臨増 167, 2014.
13. 日本糖尿病療養指導士認定機構編: 糖尿病療養指導ガイドブック 2014. メディカルレビュー社, 2014.
14. 厚生労働省 健康日本 21 評価作業チーム: 健康日本 21 最終結果. 平成 23 年 10 月.

謝辞

本研究を行うにあたって協力いただいた（一社）産業理学療法研究会の各位に深謝いたします

Ⅲ. 研究成果の刊行に関する一覧

研究成果の刊行に関する一覧表
【H26.4.1～H27.3.31】

雑誌

発表者氏名	論文タイトル名	発表誌名	巻号	ページ	出版年
Matsudaira K, Hiroe M, Kikkawa M, Suzuki M, Isomura T, Oka H, Hiroe K, Hiroe K.	Can standing back extension exercise improve or prevent low back pain in Japanese care workers?	J Man Manip Ther			in press
Hasegawa T, Katsuhira J, Matsudaira K, Iwakiri K, Maruyama H.	Biomechanical Analysis of Low Back Load when Sneezing.	Gait Posture	40	670-675	2015
Matsudaira K, Konishi H, Miyoshi K, Isomura T, Inuzuka K.	Potential risk factors of persistent low back pain developing from mild low back pain in urban Japanese workers.	PLos One	9	e93924	2014
Matsudaira K, Kikuchi N, Murakami A, Isomura T.	Psychometric properties of the Japanese version of the Fear-Avoidance Beliefs Questionnaire (FABQ).	J Orthop Sci	19	26-32	2014
Yamada K, Matsudaira K, Takeshita K, Oka H, Hara N, Takagi Y.	Prevalence of low back pain as the primary pain site and factors associated with low health-related quality of life in a large Japanese population: a pain-associated cross-sectional epidemiological survey.	Mod Rheumatol	24	343-348	2014
Muraki S, Akune T, En-yo Y, Yoshida M, Tanaka S, Kawaguchi H, Nakamura K, Oka H, Yoshimura N	Association of dietary intake with joint space narrowing and osteophytosis at the knee in Japanese men and women: The ROAD Study	Mod Rheumatol	24	236-242	2014
Muraki S, Akune T, Nagata K, Ishimoto Y, Yoshida M, Tokimura F, Tanaka S, Oka H, Kawaguchi H, Nakamura K, Yoshimura N	Association of knee osteoarthritis with onset and resolution of pain and physical functional disability: The ROAD study	Mod Rheumatol	24	966-973	2014
Hashizume H, Yoshimura N, Nagata K, Miyazaki N, Ishimoto Y, Nishiyama R, Oka H, Yamada H, Yoshida M	Development and evaluation of a video exercise program for locomotive syndrome in the elderly.	Mod Rheumatol	24	250-257	2014
Yoshimura N, Nagata K, Muraki S, Oka H, Yoshida M, Enyo Y, Kagotani R, Hashizume H, Yamada H, Ishimoto Y, Teraguchi M, Tanaka S, Kawaguchi H, Toyama Y, Nakamura K, Akune T	Prevalence and progression of the radiographic ossification of posterior longitudinal ligament and its associated factors in the Japanese populations: A 3-year follow-up of the ROAD study	Osteoporos Int	25	1089-1098	2014
Akune T, Muraki S, Oka H, Tanaka S, Kawaguchi H, Tokimura F, Yoshida H, Suzuki T, Nakamura K, Yoshimura N	Incidence of certified needed care in the long-term care insurance system and its risk factors in the elderly of Japanese population-based cohorts: the ROAD study	Geriatrics & Gerontology International	14	695-701	2014
Akune T, Muraki S, Oka H, Tanaka S, Kawaguchi H, Tokimura F, Yoshida H, Suzuki T, Nakamura K, Yoshimura N	Association of physical activities of daily living with the incidence of certified need of care in the long-term care insurance system of Japan: the ROAD study	J Orthop Sci	19	489-496	2014

Akune T, Muraki S, Oka H, Tanaka S, Kawaguchi H, Nakamura K, Yoshimura N	Exercise habits during middle age are associated with lower prevalence of sarcopenia: the ROAD study	Osteoporos Int	25	1081-1088	2014
Teraguchi M, Yoshimura N, Hashizume H, Muraki S, Yamada H, Minamide A, Oka H, Ishimoto Y, Nagata K, Kagotani R, Takiguchi N, Akune T, Kawaguchi H, Nakamura K, Yoshida M	Prevalence and distribution of intervertebral disc degeneration over the entire spine in a population-based cohort: the Wakayama Spine Study	Osteoarthritis Cartilage	22	104-110	2014
Teraguchi M, Yoshimura N, Hashizume H, Muraki S, Yamada H, Oka H, Minamide A, Nakagawa H, Ishimoto Y, Nagata K, Kagotani R, Tanaka S, Kawaguchi H, Nakamura K, Akune T, Yoshida M	The association of combination of disc degeneration, endplate signal change, and Schmorl node with low back pain in a large population study: the Wakayama Spine Study.	Spine J		pii: S1529-9430(14)01758-6. doi: 10.1016/j.spinee.2014.11.012	2014
Nagata K, Yoshimura N, Hashizume H, Muraki S, Ishimoto Y, Yamada H, Takiguchi N, Nakagawa Y, Minamide A, Oka H, Kawaguchi H, Nakamura K, Akune T, Yoshida M	The prevalence of cervical myelopathy among subjects with narrow cervical spinal canal in a population-based magnetic resonance imaging study: the Wakayama Spine Study	Spine J	14	2811-2817	2014
Yoshimura N, Akune T, Fujiwara S, Shimizu Y, Yoshida H, Omori G, Sudo A, Nishiwaki Y, Yoshida M, Shimokata H, Suzuki T, Muraki S, Oka H, Nakamura K	Prevalence of knee pain, lumbar pain and its coexistence in Japanese men and women: The Longitudinal Cohorts of Motor System Organ (LOCOMO) study	J Bone Miner Metab	32	524-532	2014
Ohya J, Miyoshi K, Oka H, Matsudaira K, Fukushima M, Nagata K.	Optimal measurement for "posterolateral protrusion" of the vertebral artery at the craniovertebral junction using computed tomography angiography	J Craniovertebr Junction Spine	5	151-156	2014
Ito H, Takatori Y, Moro T, Oshima H, Oka H, Tanaka S	Total Hip Arthroplasty After Rotational Acetabular Osteotomy	J Arthroplasty		pii: S0883-5403(14)00746-3. doi: 10.1016/j.arth.2014.10.002	2014
Ogihara S, Yamazaki T, Maruyama T, Oka H, Miyoshi K, Azuma S, Yamada T, Murakami M, Kawamura N, Hara N, Terayama S, Morii J, Kato S, Tanaka S	Prospective multicenter surveillance and risk factor analysis of deep surgical site infection after posterior thoracic and/or lumbar spinal surgery in adults	J Orthop Sci	20	71-77	2015
Ohya J, Oshima Y, Takeshita K, Oka H, Chikuda H, Taniguchi Y, Matsubayashi Y, Tanaka S	Patient satisfaction with double-door laminoplasty for cervical compression myelopathy	J Orthop Sci	20	64-70	2015

Muraki S, Akune T, En-Yo Y, Yoshida M, Suzuki T, Yoshida H, Ishibashi H,Tokimura F, Yamamoto S, Tanaka S, Nakamura K, Kawaguchi H, Oka H, Yoshimura N	Joint space narrowing, body mass index, and knee pain: the ROAD study	Osteoarthritis Cartilage		pii: S1063-4584(15)00024-2. doi: 10.1016/j.joca.2015.01.011	2015
Yoshimura N, Akune T, Fujiwara S, Shimizu Y, Yoshida H, Nishiwaki Y, Sudo A,Omori G, Yoshida M, Shimokata H, Suzuki T, Muraki S, Oka H, Nakamura K	Incidence of disability and its associated factors in Japanese men and women: the Longitudinal Cohorts of Motor System Organ (LOCOMO) study.	J Bone Miner Metab			in press
Muraki S, Akune T, Nagata K, Ishimoto Y, Yoshida M, Tokimura F, Tanaka S, Kawaguchi H, Nakamura K, Oka H, Yoshimura N.	Does osteophytosis at the knee predict health-related quality of life decline? A 3-year follow-up of the ROAD study	Clin Rheumatol			in press
Yoshimura N, Muraki S, Oka H, Nakamura K, Kawaguchi H, Tanaka S, Akune T	Serum levels of 25-hydroxyvitamin D and the occurrence of musculoskeletal diseases: a 3-year follow-up to the ROAD study	Osteoporos Int			in press
Kagotani R, Yoshida M, Muraki S, Oka H, Hashizume H, Yamada H, Enyo Y, Nagata K, Ishimoto Y, Teraguchi M, Tanaka S, Nakamura K, Kawaguchi H, Akune T, Yoshimura N	Prevalence of diffuse idiopathic skeletal hyperostosis (DISH) of the whole spine and its association with lumbar spondylosis and knee osteoarthritis: the ROAD study	J Bone Miner Metab			in press
Nakamura M, Hashizume H, Oka H, Okada M, Takakura R, Hisari A, Yoshida M, Utsunomiya H	Physical Performance Measures Associated With Locomotive Syndrome in Middle-Aged and Older Japanese Women	J Geriatr Phys Ther			in press
Yamada H, Terada M, Iwasaki H, Endo T, Okada M, Nakao S, Hashizume H, Minamide A, Nakagawa Y, Nishi H, Tsutsui S, Oka H, Yoshida M	Improved accuracy of diagnosis of lumbar intra and/or extra-foraminal stenosis by use of three-dimensional MR imaging: comparison with conventional MR imaging	J Orthop Sci			in press
Takai, Y., Yamamoto-Mitani, N., Abe Y. & Suzuki, M	Literature review of pain management for people with hronic pain	Japan Journal of Nursing Science	doi:10.1111/jjns.12065	1-17	2015

Takai, Y., Yamamoto-Mitani, N., Kawakami, S., Abe, Y., Kamiyama, M. & Saito, S	Differences between Nurses' and Care workers' Estimations of Pain Prevalence among Elderly Residents	Pain Management Nursing	16 (1)	20-32	2015
Takai, Y., Yamamoto-Mitani, N., & Ko, A.	Prevalence of and factors related to pain among elderly Japanese residents in long-t erm healthcare facilities	Geriatrics & Gerontology International	14(2)	481-9	2014

Ⅳ. 研究成果の刊行物・別刷

G Model
GAIPOS-4269; No. of Pages 6

ARTICLE IN PRESS

Gait & Posture xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Biomechanical analysis of low back load when sneezing

Tetsuya Hasegawa [a,*], Junji Katsuhira [b], Ko Matsudaira [c], Kazuyuki Iwakiri [d], Hitoshi Maruyama [a]

[a] Graduate School, International University of Health and Welfare, 2600-1 Kitakanemaru, Otawara, Tochigi 324-8501, Japan
[b] Department of Odawara Health Science, International University of Health and Welfare, 1-2-25 Shiroyama, Odawara, Kanagawa 250-8588, Japan
[c] Department of Medical research and Management for Musculoskeletal pain,22nd Century Medical and Research Center, The University of Tokyo,7-3-1,Hongo,Bunkyo-ku,Tokyo,113-8655, Japan
[d] National Institute of Occupational Safety and Health, Nagao 6-21-1, Tama-ku, Kawasaki, Kanagawa 214-8585, Japan

ARTICLE INFO

Article history:
Received 2 September 2013
Received in revised form 29 May 2014
Accepted 22 July 2014

Keywords:
Sneeze
Low back load
Low back pain
Intervertebral disk compressive force
Low back moment

ABSTRACT

Background: Although sneezing is known to induce low back pain, there is no objective data of the load generated when sneezing. Moreover, the approaches often recommended for reducing low back pain, such as leaning with both hands against a wall, are not supported by objective evidence.
Methods: Participants were 12 healthy young men (mean age 23.25 ± 1.54 years) with no history of spinal column pain or low back pain. Measurements were taken using a three-dimensional motion capture system and surface electromyograms in three experimental conditions: normal for sneezing, characterized by forward trunk inclination; stand, in which the body was deliberately maintained in an upright posture when sneezing; and table, in which the participants leaned with both hands on a table when sneezing. We analyzed and compared the intervertebral disk compressive force, low back moment, ground reaction force, trunk inclination angle, and co-contraction of the rectus abdominis and erector spinae muscles in the three conditions.
Findings: The intervertebral disk compressive force and ground reaction force were significantly lower in the stand and table conditions than in the normal condition. The co-contraction index value was significantly higher in the stand condition than in the normal and table conditions.
Interpretation: When sneezing, body posture in the stand or table condition can reduce load on the low back compared with body posture in the normal sneezing condition. Thus, placing both hands on a table or otherwise maintaining an upright body posture appears to be beneficial for reducing low back load when sneezing.

1. Introduction

Low back pain (LBP) is a common and major health problem, which can have sizeable socioeconomic impacts due to substantial direct and indirect social costs associated with LBP-related disability and loss of work [1,2]. In fact, most adults at some point in their lives experience some degree of LBP, of which approximately 85–90% of cases are classified as non-specific LBP [3,4]. In some instances, LBP is characterized as recurrent [5,6]. A recent report in Japan suggested that the lifetime prevalence of LBP was as high as 83% and the 4-week prevalence was 36%, making it the fifth-most common reason for medical consultation among outpatients [7].

Various factors can cause acute onset of non-specific LBP, including lifting and bending [8], and strategies for reducing low back load during such actions have been investigated from a biomechanical viewpoint using indicators for low back load such as the low back moment (LBM) and intervertebral disk compressive force (CF) in the lower back [9,10]. In clinical practice, sneezing is often reported to aggravate LBP. Indeed, Walker et al. reported sneezing to be an indicator of mechanical LBP [11], and Vroomen et al. [12] observed that 33% (40/122) of patients with LBP radiating in the leg but without radicular syndrome felt more pain on coughing, sneezing, or straining.

Sneezing occurs frequently as a respiratory reflex triggered to expel foreign bodies that mechanically irritate the nasal mucosa [13,14]. Characterized by explosive exhaling, sneezing is said to

* Corresponding author. Tel.: +81 0287 24 3000; fax: +81 0287 24 3100.
E-mail address: hasegawatetsuya1986@gmail.com (T. Hasegawa).

http://dx.doi.org/10.1016/j.gaitpost.2014.07.020
0966-6362/

Please cite this article in press as: Hasegawa T, et al. Biomechanical analysis of low back load when sneezing. Gait Posture (2014), http://dx.doi.org/10.1016/j.gaitpost.2014.07.020

cause strong concentric contraction of the rectus abdominis (RA) muscles and often sudden forward inclination of the trunk when in an upright posture. This forward inclination increases the lever arm from the center of rotation of the lower back to the center of mass in the upper body, thereby increasing the LBM. Moreover, since the forward trunk inclination angle (TA) is suddenly increased while sneezing, it is assumed that the acceleration applied to the center of gravity (COG) of the trunk also increases. This increase in acceleration entails a strong increase in the force that bends the trunk, so the erector spinae (ES) muscles must contract to maintain posture. Forward trunk inclination and ES contraction are reported to increase the CF [15], and therefore sneezing can be regarded as an action that increases low back load. However, no studies to date have reported objective measurement and biomechanical analysis of the low back load when sneezing.

Various types of media targeting people with LBP often recommend maintaining an upright posture or leaning with both hands on a table when sneezing to counter such pain [16]. These recommendations are made despite the lack of evidence for their efficacy. In this study, we conducted biomechanical tests to verify the hypothesis that maintaining an upright position or leaning with both hands on a table when sneezing reduces the low back load.

2. Methods

2.1. Subjects

Participants were 12 healthy young men (mean age, 23.25 SD 1.54 years; mean height, 170.30 SD 4.00 cm; mean weight, 60.90 SD 7.39 kg) with no history of LBP or spinal column pain. All provided written consent to participate after the study protocol was approved by institutional ethics committees.

2.2. Experimental conditions

Measurements were conducted under the following three conditions (Fig. 1): NORMAL condition for sneezing, characterized by forward trunk inclination; STAND condition, deliberately maintaining an upright posture of the trunk when sneezing; and TABLE condition, bending the trunk and leaning with both hands on a table when sneezing. Subjects stood on force plates and freely chose the distance between their feet and the position of their hands on the table. Subjects induced sneezing by irritating the nasal mucosa with a long, thin strip of tissue paper [17]. Measurements were taken 3 times under each experimental condition. In total, 9 trials with 1-min recovery intervals were conducted.

2.3. Experimental setup

Fig. 1 shows the measurement system used. Movement was recorded with a three-dimensional (3D) motion capture system (Vicon 612, Vicon, Oxford, UK) consisting of four force plates (AMTI, Watertown, MA) and 12 infrared cameras with a sampling rate of 120 Hz. Thirty-two infrared (IR)-reflective markers (diameter, 14 mm) were attached to each subject: top of the head, C7 spinous process, T10 spinous process, L5 spinous process, manubrium sterni, xiphoid process and bilaterally on the acromion process, lateral epicondyle, ulnar styloid process, anterior and posterior superior iliac spine, iliac crest, acetabulofemoral joint, medial knee joint, lateral knee joint, medial and lateral malleoli, and the first and fifth metacarpophalangeal joints. The obtained physical coordinates and ground reaction force (GRF) data were processed with a 6 Hz and 18 Hz second-order low-pass Butterworth filter (dual-pass for zero lag), respectively [18].

To measure muscle activity during movement, electromyograms were obtained (Biometrics, Newport, UK) at a sampling rate of 1000 Hz for the right RA (1 cm to the side of the umbilical region and 2 cm to the side of the medial line) [19] and the right ES (2 cm to the side between the L4 and 5 vertebrae) [20]. Electrodes were attached to only the right side because the left and right sides were expected to behave in a similar manner. Electromyography signals were prefiltered, producing a bandwidth of 20–460 Hz, and amplified with a differential amplifier (common-mode rejection ratio > 96 dB at 60 Hz, input impedance > 10 TΩ). Subjects wore a wristband connected to the grounding electrodes on the right hand. Subjects performed in the supine position against gravity with maximum resistance applied by the experimenter to obtain the maximum voluntary contraction of the RA (sit-up with straight leg while imposing resistance to the breast region) and in the prone position to obtain the maximum voluntary contraction of the ES (back extension with their hand resting on their head while imposing resistance to the scapular region) [21]. The subjects were required to produce maximal isometric extension efforts while resistance was provided by a single examiner with a physical therapy license.

Pressure sensors (DKH, Tokyo, Japan) were connected to the electromyographs and force plates to synchronize the

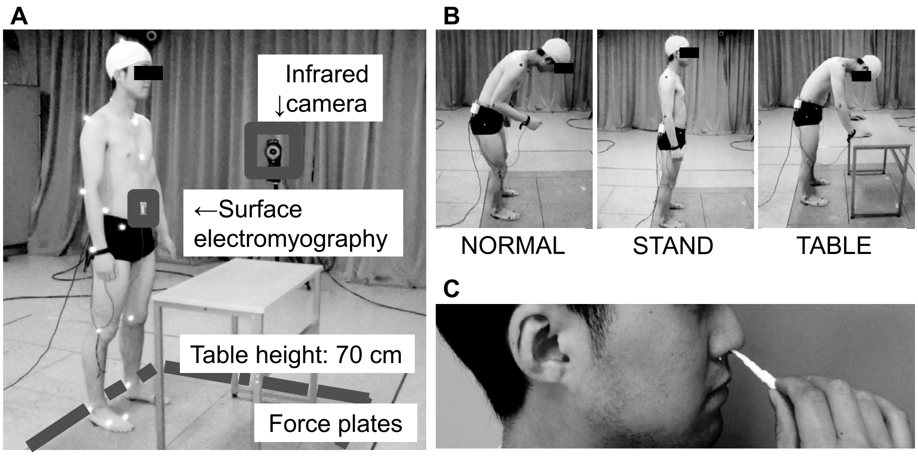

Fig. 1. (A) Experimental setup. (B) The three experimental sneezing conditions examined. In the NORMAL condition, subjects sneezed with no instructions. In the STAND condition, subjects were instructed to maintain an upright position as long as possible. In the TABLE condition, subjects were instructed to immediately place both hands on the table when they felt they would sneeze. (C) To promote sneezing, each volunteer irritated his nasal area using a roll made by twisting a sheet of tissue paper.

Please cite this article in press as: Hasegawa T, et al. Biomechanical analysis of low back load when sneezing. Gait Posture (2014), http://dx.doi.org/10.1016/j.gaitpost.2014.07.020

electromyograms and graphs obtained with the Vicon system. The observer input an analog electrical pulse as the synchronization marker to send to all systems to identify a common temporal reference point at the beginning of the measurement.

2.4. Data analysis

Data were analyzed using the 3D motion analysis software package Vicon Body Builder (Vicon). The method of Katsuhira et al. [9,10] was used to calculate the LBM. Briefly, the LBM was calculated using inverse dynamic analysis based on the Newton–Euler method from the GRF data obtained from the coordinates of the IR-reflective markers and force plates. In the analysis, segments were regarded as rigid and the joint moment was calculated using a link segment model in which segments were connected together at nodal points. To compute the joint moment, muscle coordinate data were added to the GRF data, in which the position of the center of mass, the weight portion, and the moment of inertia of each segment were used as parameters. The measurement data reported by Winter et al. [18], Okada et al. [23] and Jorgensen et al. [24] were used as the body parameters necessary for calculating the LBM. The method by Katsuhira et al. [25] was used to calculate the CF. Because LBP is often reported to occur between L4 and L5 [26], the L4–5 interspace was taken as the center of rotation for the LBM. The moment arm of the intervertebral disks and muscles was taken as the distance between the intervertebral disks and RA upon generation of the low back flexion moment and as the distance between the disks [23] and ES upon generation of the low back extension moment [24].

When calculating the CF in TABLE, the table was set to straddle the force plates, and the weight of the table was excluded from the calculations. In addition, the GRF readings obtained from the force plates on which the table was mounted were decomposed in accordance with the TA, and the reaction force obtained from the table was calculated by subtracting the result from the CF. Formula 1 refers to the CF [25]. Here, 20, 13, 8, and 23 are inverse numbers of the moment arms [23–25]. The low back joint compression force was obtained by multiplying the inverse number of the moment arms by the absolute value of the low back joint moments for each axis and adding the resolved gravitational force applied to the COG of the head, arm, and trunk (HAT) and the TA (θ):

$$\begin{aligned}&\text{Intervertebral disk CF}\\ &+20|\text{Extension moment}|\text{or}13|\text{Flexion moment}|\\ &+8|\text{Side flexion moment}|\\ &+23|\text{Rotation moment}|\\ &+\text{Gravitational force applied to COG of HAT}\cdot\cos\theta\\ &-\text{Reaction force from table}\cdot\cos\theta\end{aligned} \tag{1}$$

The LBM and CF calculated with the above methods were taken as indicators of low back load. By taking the markers on both shoulders and manubrium sterni as indicators, the TA was measured as the change in angle when standing and the angle at peak CF when sneezing.

The co-contraction index (CCI) was calculated according to Falconer and Winter [27] to evaluate the co-contraction of the RA and ES when sneezing. Electromyographic data from these muscles were integrated over 1000 frames from a 1-s period (0.5 s before to 0.5 s after) of the peak CF recorded when sneezing. Using the obtained integral value, we calculated the portion corresponding to co-contraction of the muscles, which was taken as CCI. The computation of I_{ant}, which refers to the integral of the electromyogram of the antagonist muscle, shows the signal was stronger for the RA than for the ES between $t1$ and $t2$, and vice versa between $t2$ and $t3$, where t is timing. $\mathrm{EMG}_{\mathrm{AB}}$ and $\mathrm{EMG}_{\mathrm{ES}}$ indicate the activities of the RA and ES, respectively.

Consequently, the calculation was as follows:

$$I_{\mathrm{ant}} = \int_{t1}^{t2} \mathrm{EMG}_{\mathrm{AB}}(t)dt + \int_{t2}^{t3} \mathrm{EMG}_{\mathrm{ES}}(t)dt \tag{2}$$

here I_{total} denotes the added integral values for these muscles, and $\mathrm{EMG}_{\mathrm{agon}}$ and $\mathrm{EMG}_{\mathrm{ant}}$ denote the electromyogram of the agonist and antagonist muscles, respectively. CCI was calculated from these values as follows:

$$I_{\mathrm{total}} = \int_{t4}^{t3} [\mathrm{EMG}_{\mathrm{agon}} + \mathrm{EMG}_{\mathrm{ant}}](t)dt \tag{3}$$

$$\mathrm{CCI} = \frac{2I_{\mathrm{ant}}}{I_{\mathrm{total}}} \times 100\% \tag{4}$$

Data for the CF, GRF, LBM, and TA were extracted at peak CF, and the CF, GRF, and LBM were normalized by body weight (mean of three measurements) to decrease individual differences.

2.5. Statistical analysis

Statistical analysis was performed using the mean values of the parameters for each participant and comparing the CF, LBM, GRF, TA, and CCI for the three experimental conditions. Verification was performed using repeated measures ANOVA, and variables showing a significant difference were subjected to multiple comparisons with Bonferroni correction. Significance was set at 5%. Intra-class correlation coefficients (ICC) of peak low back CF from the three trials were calculated for each condition. Statistical analysis was performed using SPSS 20 (SPSS Inc., Chicago, IL).

3. Results

3.1. Intervertebral disk compressive force and low back moment

The CF waveform in NORMAL shows two peaks, peak 1 and peak 2 (Fig. 2). The LBM waveform shows the flexion moment generated first, followed by the extension moment. Both the CF and LBM showed similar tendencies in all conditions.

Fig. 3 shows the mean CF for each condition. ICCs indicated moderate reliability in each condition. The force in STAND and TABLE was about half that in NORMAL. Table 1 shows the CF for peak 1, peak 2, and over a sneeze normalized by each subject's weight. Compared with NORMAL, these forces were significantly lower in STAND and TABLE ($p < 0.05$).

Table 1 shows the values for the LBM normalized by subject weight at peak CF. The force peaked when the low back extension moment was generated in NORMAL and TABLE and when the low back flexion moment was generated in STAND.

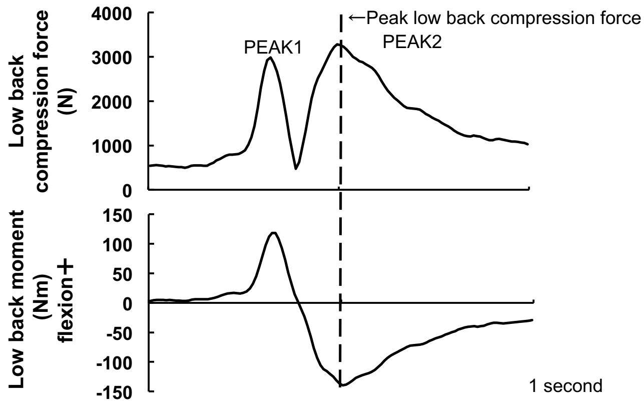

Fig. 2. Single data for low back compression force and joint moment when sneezing in the normal condition. Wave patterns 0.5 s before and after peak low back compression force are shown because this duration included the start and end of the sneeze in all subjects using a wave form of compressive force. The start and end of the sneeze was therefore defined as 0.5 s before and 0.5 s after peak intervertebral disk compressive force.

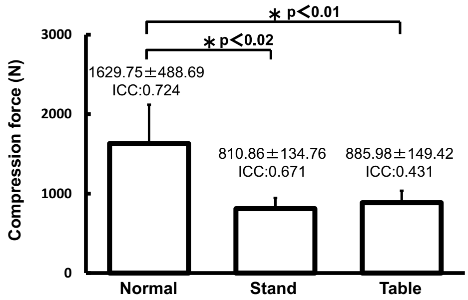

Fig. 3. Comparison of intervertebral disk compressive force of mean peak values and intra-class correlation coefficients (ICCs) in each experimental condition.

3.2. Vertical ground reaction force

Table 1 shows the GRF values normalized by subject weight at peak CF. The vertical component decreased significantly in STAND and TABLE compared with NORMAL ($p < 0.001$). No significant difference was seen between STAND and TABLE.

3.3. Change in trunk inclination angle

Table 1 shows the changes in the TA between standing posture and at peak CF. The positive direction is taken in the direction of flexion. The change was in the direction of flexion in NORMAL and TABLE, but in the direction of extension in STAND ($p < 0.001$). No significant difference was observed between NORMAL and TABLE.

3.4. Electromyograms and CCI

The electromyogram waveform for NORMAL indicates high activity for both the RA and ES when sneezing (Fig. 4). Furthermore, the CF and ES activity peaked at roughly the same time, and CCI was significantly higher in STAND than in NORMAL and TABLE ($p < 0.001$) (Table 1).

4. Discussion

4.1. Low back moment and intervertebral disk compressive force when sneezing

Two peaks were found in the plots of CF and LBM when sneezing, indicating that the RA is highly active during the characteristic forceful exhalation of sneezing. Such muscle activity induces flexion of the trunk, which activates the ES to maintain posture. Electromyograms also showed that since the activity of the RA peaked before that of the ES, the former is predominantly active during generation of the low back flexion moment, while the latter is more active during generation of the low back extension moment.

The mean CF when sneezing in NORMAL for a young man of approximately 60 kg is about 1600 N. This is roughly equivalent to holding a 20-kg load in a stationary upright position, which results in an estimated 3- or 4-fold increase in CF on the L4–5 intervertebral disks during static standing [15]. In other words, although sneezing is a momentary action, the load exerted on the intervertebral disks might aggravate or cause recurrent LBP.

Among the three experimental conditions, the CF and LBM were significantly lower in STAND and TABLE. The LBM was estimated from the GRF using the inverse dynamics method. This moment is influenced by the TA, and the GRF reflects the acceleration generated as a result of trunk movement. For this reason, the CF can probably be decreased by reducing these two parameters. There are a number of possible reasons for the significantly lower CF in STAND and TABLE. First, the change in TA was comparatively small in STAND, meaning that the moment arm of the center of mass of the upper body with respect to the intervertebral disks is small, so it can be considered to reduce the LBM. In the aforementioned study measuring the CF [15], the force increased with flexion of the trunk, a tendency similar to that observed in the present study. In addition, the vertical GRF was small compared with NORMAL. This might have resulted from deliberately maintaining an upright posture, where the acceleration of the trunk was suppressed by consciously stopping the trunk from moving.

Second, the CF peaked during generation of the flexion moment only in STAND. This force is considered to peak when the RA is active. Because this moment arm is about 1.5-fold longer than that for the ES [24], the tensile force exerted by the RA is smaller, which reduces the CF.

Third, in TABLE, the vertical GRF was reduced and the LBM was significantly reduced compared with NORMAL. No significant difference was seen in the magnitude of TA change. Furthermore, compared with NORMAL, the GRF acting on the feet as a result of leaning with both hands on the table was reduced, which suppressed movement of the trunk when sneezing.

Table 1
Comparison with the normal sneezing posture of mean peak values at peak intervertebral disk compressive force and standard deviations of each of the parameters measured in the standing upright posture and leaning with hands on a table posture. The waveform of intervertebral disk compressive force shows two peaks. PEAK1 and PEAK2 indicate the first and second peak of the compression force, respectively. Verification was performed with repeated measures ANOVA using the different sneeze conditions as factors.

	Normal	Stand	Table	*p*-value
Compression force (N/kg) (PEAK1)	16.37 SD 5.09	12.36 SD 1.99[a1]	8.88 SD 3.50[a2]	$p < 0.001^*$ a1: $p < 0.001$ a2: $p < 0.031$
Compression force (N/kg) (PEAK2)	26.09 SD 6.16	11.198 SD 2.65[a1]	9.37 SD 3.00[a2]	$p < 0.001^*$ a1: $p < 0.001$ a2: $p < 0.001$
Compression force (N/kg) (Over sneezing)	26.75 SD 6.44	13.24 SD 2.32[a1]	14.04 SD 1.50[a2]	$p < 0.001^*$ a1: $p < 0.001$ a2: $p < 0.001$
Moment (Nm/kg) (Extension+)	−0.90 SD 0.38	0.27 SD 0.21[b]	−0.45 SD 0.33	$p < 0.001^*$ b: $p < 0.001$
Ground reaction force (N/kg)	10.77 SD 0.55	9.67 SD 0.58[a1]	8.93 SD 0.86[a2]	$p < 0.001^*$ a1: $p < 0.001$ a2: $p < 0.001$
Co-contraction index (%)	31.99 SD 8.07	44.83 SD 8.15[b]	31.00 SD 7.71	$p < 0.001^*$ b: $p < 0.001$
Trunk angle (°) (Flexion+)	31.05 SD 12.24	−4.44 SD 6.25[a]	36.47 SD 6.29	$p < 0.001^*$ a: $p < 0.001$

* One-way analysis of variance: (a) significantly smaller than in the normal condition on multiple comparison ($p < 0.05$); (b) larger than the other two conditions on multiple comparison ($p < 0.05$).

Please cite this article in press as: Hasegawa T, et al. Biomechanical analysis of low back load when sneezing. Gait Posture (2014), http://dx.doi.org/10.1016/j.gaitpost.2014.07.020

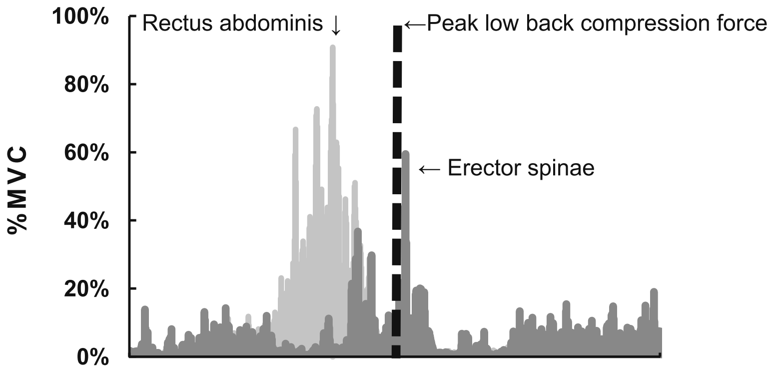

Fig. 4. Surface electromyography of the erector spinae and rectus abdominis muscles showing maximal voluntary contraction. During acquisition, we performed full-wave rectification using WAD analysis software (DKH, Tokyo, Japan) and a band-pass filter (20–420 Hz) to decrease noise according to the methods reported by Cholewicki et al. [22]. The obtained electromyograms were normalized using maximal voluntary contraction during isometric contraction. The wave pattern shows 0.5 s before and after the peak low back compression force.

4.2. Differences between conditions induced by muscle activity

Comparing the three conditions from the viewpoint of muscle activity, we found that CCI was significantly higher in STAND. In other words, there is greater co-contraction of the RA and ES in STAND. Co-contraction of antagonist muscles in the trunk increases the CF and stabilizes the upper trunk [28,29]. Arjmand et al. [29] suggested that co-contraction of antagonist muscles in the trunk is effective for stabilizing the upper trunk while lifting a heavy load. However, the low back load while sneezing was not as large as that when lifting a heavy load.

The present calculations transforming joint moment to muscle force did not separately clarify the magnitude of muscle force generated by the agonist and antagonist muscles. The CF might be greater in STAND than in NORMAL due to the CF generated by muscle co-contraction. Given that CCI was significantly higher in the STAND, greater CF seems to be generated by muscle co-contraction. Therefore, this force is more likely to be reduced in TABLE than in STAND. In other words, leaning with both hands on a table is more suitable for reducing the risk of low back load generated when sneezing than deliberately maintaining an upright posture.

This study has some limitations. First, the subjects were healthy young men, so it will be necessary to conduct a further study considering sex, age, and morphological differences and include subjects with LBP. Second, since the tensile forces exerted by the agonist and antagonist trunk muscles were not calculated separately, the CF generated by muscle co-contraction would not be entirely correct. Third, a previous study reported that high intra-abdominal pressure (IAP) might harm the lumbar tissues and cause LBP. Our biomechanical model accounted for the LBM including the effect of IAP but not the direct effect of IAP on low back load. Fourth, other factors, such as neck position and internal muscular or cardiovascular pressures, while sneezing should be examined.

Prevention measures for low back disability require continuous awareness of the fear avoidance (FA) model, because making the patient aware of posture while sneezing might cause an opposite effect to that desired [30]. Although we could not show the effect of FA in this study, future studies should consider the FA model when observing the effects of preventive measures for low back load while sneezing.

Conflicts of interest statement

None.

Acknowledgments

This study was supported by the Japan Labor Health and Welfare Organization's dissemination project Thirteen Fields of Occupational Injuries and Illness.

References

[1] Manchikanti L, Singh V, Datta S, Cohen SP, Hirsc JA. American society of interventional pain physicians. Comprehensive review of epidemiology, scope, and impact of spinal pain. Pain Physician 2009;12:E35–70.
[2] Dagenais S, Caro J, Haldeman S. A systematic review of low back pain cost of illness studies in the United States and internationally. Spine J 2008;8:8–20.
[3] Krismer M, van Tulder M. Low back pain (non-specific). Best Pract Res Clin Rheumatol 2007;21:77–91.
[4] Deyo RA, Rainville J, Kent DL. What can the history and physical examination tell us about low back pain? JAMA 1992;268:760–5.
[5] Carey TS, Garrett JM, Jackman A, Hadler N. Recurrence and care seeking after acute back pain: results of a long-term follow-up study. North Carolina Back Pain Project. Med Care 1999;37:157–64.
[6] Pengel L, Herbert R, Maher CG, Refshauge KM. Acute low back pain: a systematic review of its prognosis. BMJ 2003;327:323–7.
[7] Fujii T, Matsudaira K. Prevalence of low back pain and factors associated with chronic disabling back pain in Japan. Eur Spine J 2013;22(2):432–8 [Epub 2012 August 7].
[8] Vingard E, Nachemson AL. Work-related influences on neck and low back pain. In: Nachemson AJ, Jonsson E, editors. Neck and back pain: the scientific evidence of causes, diagnosis and treatment. Philadelphia, PA: Lippincot Williams & Wilkins; 2000. p. 97–126.
[9] Katsuhira J, Sasaki H, Asahara S, Ikegami T, Ishihara H, Kikuchi T, et al. Comparison of low back joint movement using a dynamic 3D biomechanical model in different transferring tasks wearing low back belt. Gait Posture 2008;28:258–64.
[10] Katsuhira J, Tomita S, Haraguchi T, Harada S, Isikawa E, Kubo T, et al. Effect of use and type of assistive devices and posture while using them on the low back load in transferring Tasks. Jpn J Ergon 2010;46:157–65 [in Japanese].
[11] Walker BF, Williamson OD. Mechanical or inflammatory low back pain. What are the potential signs and symptoms? Man Ther 2009;14:314–20.
[12] Vroomen PCAJ, de Krom MCTFM, Wilmink JT, Kester ADM, Knottnerus JA. Diagnostic value of history and physical examination in patients suspected of lumbosacral nerve root compression. J Neurol Neurosurg Psychiatry 2002;72:630–4.
[13] Batsel HL, Lines AJ. Neural mechanism of sneeze. Am J Physiol 1975;229:770–6.
[14] Richardson PS, Peatfield AC. Reflexes concerned in the defence of the lungs. Bull Eur Physiopathol Respir 1981;17:979–1012.
[15] Wilke HJ, Neef P, Caimi M, Hoogland T, Claes LE. New in vivo measurements of pressures in the intervertebral disc in daily life. Spine 1999;24:755–62.
[16] Japan Labour Health and Welfare Organization website. Available from: http://www.research12.jp/22_kin/docs/manual.pdf [accessed 17.11.11] [in Japanese].
[17] Nishimura H, Sakata S, Kaga A. A new methodology for studying dynamics of aerosol particles in sneeze and cough using a digital high-vision, high-speed video system and vector analyses. PLOS ONE 2013;8(11):e80244.
[18] Winter DA. Biomechanics and motor control of human movement. 3rd ed. New York: John Wiley & Sons, Inc.; 2004.
[19] Ng JK, Kippers V, Richardson CA. Muscle fibre orientation of abdominal muscles and suggested surface EMG electrode positions. Electromyogr Clin Neurophysiol 1998;38:51–8.

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[20] De Foa JL, Forrest W, Biedermann HJ. Muscle fibre direction of longissimus, iliocostalis and multifidus: landmark-derived reference line. J Anat 1989;163: 243–7.
[21] Hislop HJ, Montgomery J. Daniels and Worthingham's muscle testing: techniques of manual examination. 8th ed. Philadelphia: Saunders; 2007.
[22] Cholewicki J, McGill KC, Shah KR, Lee AS. The effects of a three-week use of lumbosacral orthoses on trunk muscle activity and on the muscular response to trunk perturbations. BMC Musculoskelet Disord 2010;11(1): 154.
[23] Okada H, Michiyoshi AE, Fujii N, Morioka Y. Body segment inertia properties of Japanese elderly. Biomechanisms 1996;13:125–39 [in Japanese].
[24] Jorgensen MJ, Marras WS, Granata KP, Wiand JW. MRI-derived moment-arms of the female and male spine loading muscles. Clin Biomech (Bristol Avon) 2001;16:182–93.
[25] Katsuhira J, Matsudaira K, Iwakiri K, Kimura V, Ohashi T, Ono R, et al. Effect of mental processing on low back load while lifting an object. Spine 2013;38:832–9.
[26] Chaffin DB, Anderson GBJ, Martin BJ. Occupational biomechanics. New York: John Wiley & Sons, Inc.; 1999.
[27] Falconer K, Winter DA. Quantitative assessment of co-contraction at the ankle joint in walking. Electromyogr Clin Neurophysiol 1985;25:135–49.
[28] Cholewicki J, Ivancic PC, Radebold A. Can increased intra-abdominal pressure in humans be decoupled from trunk muscle co-contraction during steady state isometric exertions? Eur J Appl Physiol 2002;87:127–33.
[29] Arjmand N, Shirazi-Adl A, Parnianpour M. Relative efficiency of abdominal muscles in spine stability. Comput Methods Biomech Biomed Eng 2008;11:291–9.
[30] Fujii T, Matsudaira K, Oka H. Factors associated with fear-avoidance beliefs about low back pain. J Orthop Sci 2013;18:909–15.

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Potential Risk Factors of Persistent Low Back Pain Developing from Mild Low Back Pain in Urban Japanese Workers

Ko Matsudaira[1*¤a], Hiroaki Konishi[2], Kota Miyoshi[3¤b], Tatsuya Isomura[4¤c], Kyoko Inuzuka[4]

1 Clinical Research Center for Occupational Musculoskeletal Disorders, Kanto Rosai Hospital, Kawasaki, Kanagawa, Japan, **2** Department of Orthopaedic Surgery, Nagasaki Rosai Hospital, Sasebo, Nagasaki, Japan, **3** Spine Center, Yokohama Rosai Hospital, Yokohama, Kanagawa, Japan, **4** Clinical Research Department, CLINICAL STUDY SUPPORT, Inc., Nagoya, Aichi, Japan

Abstract

Study Design: Two-year, prospective cohort data from the Japan epidemiological research of occupation-related back pain study in urban settings were used for this analysis.

Objective: To examine the association between aggravated low back pain and psychosocial factors among Japanese workers with mild low back pain.

Summary of Background Data: Although psychosocial factors are strongly indicated as yellow flags of low back pain (LBP) leading to disability, the association between aggravated LBP and psychosocial factors has not been well assessed in Japanese workers.

Methods: At baseline, 5,310 participants responded to a self-administered questionnaire including questions about individual characteristics, ergonomic work demands, and work-related psychosocial factors (response rate: 86.5%), with 3,811 respondents completing the 1-year follow-up questionnaire. The target outcome was aggravation of mild LBP into persistent LBP during the follow-up period. Incidence was calculated for the participants with mild LBP during the past year at baseline. Logistic regression was used to explore risk factors associated with persistent LBP.

Results: Of 1,675 participants who had mild LBP during the preceding year, 43 (2.6%) developed persistent LBP during the follow-up year. Multivariate analyses adjusted for individual factors and an ergonomic factor found statistically significant or almost significant associations of the following psychosocial factors with persistent LBP: interpersonal stress at work [adjusted odds ratio (OR): 1.96 and 95% confidence interval (95%CI): 1.00–3.82], job satisfaction (OR: 2.34, 95%CI: 1.21–4.54), depression (OR: 1.92, 95%CI: 1.00–3.69), somatic symptoms (OR: 2.78, 95%CI: 1.44–5.40), support from supervisors (OR: 2.01, 95%CI: 1.05–3.85), previous sick-leave due to LBP (OR: 1.94, 95%CI: 0.98–3.86) and family history of LBP with disability (OR: 1.98, 95%CI: 1.04–3.78).

Conclusions: Psychosocial factors are important risk factors for persistent LBP in urban Japanese workers. It may be necessary to take psychosocial factors into account, along with physical work demands, to reduce LBP related disability.

Citation: Matsudaira K, Konishi H, Miyoshi K, Isomura T, Inuzuka K (2014) Potential Risk Factors of Persistent Low Back Pain Developing from Mild Low Back Pain in Urban Japanese Workers. PLoS ONE 9(4): e93924. doi:10.1371/journal.pone.0093924

Editor: Laxmaiah Manchikanti, University of Louisville, United States of America

Received December 11, 2013; **Accepted** March 10, 2014; **Published** April 8, 2014

Funding: The study was a part of clinical research projects conducted by the Japan Labor Health and Welfare Organization. The research projects aimed to resolve occupational health issues and disseminate the research findings. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing Interests: TI is a founder of CLINICAL STUDY SUPPORT, Inc. KI is an employee of CLINICAL STUDY SUPPORT, Inc. This does not alter the authors' adherence to all the PLOS ONE policies on sharing data and materials.

* E-mail: kohart801@gmail.com

¤a Current address: Department of Medical Research and Management for Musculoskeletal Pain, 22nd Century Medical and Research Center, Faculty of Medicine, The University of Tokyo, Bunkyo-ku, Tokyo, Japan
¤b Current address: Department of Orthopaedic Surgery, Yokoyama Rosai Hospital, Yokohama, Kanagawa, Japan
¤c Current address: Clinical Research Department, CLINICAL STUDY SUPPORT, Inc., Nagoya, Aichi, Japan; Division of Clinical Research Consultation, Institute of Medical Science, Tokyo Medical University, Tokyo, Japan

Introduction

Low back pain (LBP) is a common musculoskeletal occupational health problem in industrialized countries and was found to be the leading specific cause of years lived with disability [1]. Japan is no exception, and LBP is one of the five most common health complaints of the Japanese general population [2]. Typically, 85–90% of the cases are classified as 'non-specific' [3,4], and the majority of LBP is mild, so they do not become severely disabled [5,6]. However, in terms of cost and work loss, the small proportion of people who become disabled due to LBP account for the largest occupational health care cost and the greatest number of work days lost around the world [7,8]. Therefore, clarifying potential risk factors that could aggravate the LBP condition and lead to disability to work would be very important.

Many epidemiological studies of LBP have been conducted worldwide for decades. Psychosocial factors such as low job satisfaction, depression, or the tendency to somatize have been strongly indicated as 'yellow flags' for LBP leading to disability, as have ergonomic factors such as physical work demands [8–11], although the magnitude or intensity of each factor may vary across cultures or work environments [12]. Based on the above evidence, recently in Japan psychosocial factors began to be considered as a major risk for aggravating LBP. However, to our knowledge, the association between aggravation of Japanese workers' back pain and psychosocial factors has not been thoroughly assessed in prospective epidemiological research studies.

Previously, we reported potential risk factors for new onset of back pain disability in Japanese workers enrolled in a prospective cohort study in urban settings [13]. Data regarding various potential risk factors at baseline, as well as LBP-related outcomes, were collected prospectively. The cohort study focused mainly on LBP that caused work disability, a subject of critical importance to employers as well as workers, in terms of occupational health care.

The present study was designed to ascertain whether various psychosocial factors are associated with aggravating mild LBP into persistent LBP in workers with a 1-year history of mild LBP, using data from the previously reported cohort study; the findings of this further data analysis are reported here. This study was part of a series of clinical research projects conducted by the Japan Labor, Health and Welfare Organization related to 13 fields of occupational injuries and illnesses, including musculoskeletal disorders, mental health, and cancer. The research projects were conducted to help resolve occupational health issues and to disseminate the findings.

Materials and Methods

Data source

Data were extracted from a prospective cohort of the "The Japan epidemiological research of Occupation-related Back pain (JOB)" study. Participants were recruited from 16 workplaces in various occupational fields, located in or near Tokyo. The major occupational groups at these workplaces were office workers, nurses, sales/marketing personnel, and manufacturing engineers. Each participating organization was asked to distribute a self-administrated questionnaire to their workers, along with a cover letter from the study administration office. Respondents were asked to return their completed questionnaires by post, including their names and mailing addresses, which were used to send follow-up questionnaires directly from the study administration office. A total of 6,140 baseline questionnaires were distributed during September 2005 and February 2006, and 5,310 completed questionnaires were returned (response rate: 86.5%).

The baseline questionnaire included questions about the severity of the respondent's LBP and various individual and work-related factors. LBP severity was evaluated by the respondents themselves, who were asked to quantify the severity into one of four grades: grade 0, no LBP; grade 1, LBP not interfering with work; grade 2, LBP interfering with work; and grade 3, LBP interfering with work and leading to sick leave. The grades were determined with reference to Von Korff's grading method [14]. LBP was defined as pain localized between the costal margin and the inferior gluteal folds [3], and the area was depicted in the questionnaire. The baseline questionnaire included questions about the following: individual characteristics, including gender, age, obesity, smoking habits, history of LBP, and previous sick leave due to LBP; ergonomic work demands, such as frequency of bending, twisting or lifting at work; and psychosocial factors, such as depression, interpersonal stress at work, job control, job satisfaction, and somatization. A brief job stress questionnaire (BJSQ) was used to evaluate the major psychosocial factors [15,16]. The BJSQ is a self-administered scale having a total of 57 items, developed by a research working group organized by the Japan Labour, Health and Welfare Organization. Question items for the questionnaire were extracted from standard questionnaires commonly used for evaluating stress related factors, psychological stress response, depression, anxiety, and somatization [17–23]. The questionnaire was assessed using standardized scores, which were classified into 19 work-related stress factors: mental workload (quantitative aspect), mental workload (qualitative aspect), physical workload, interpersonal stress at work, environmental work stress, job control, utilization of skills and expertise, physical fitness, job satisfaction, vigor, irritability, fatigue, anxiety, depression, somatic symptoms, support from supervisors, support from co-workers, support from family or friends, and daily-life satisfaction. For each factor above, standardized scores were developed on a 5-point scale ranging from 1 (lowest) to 5 (highest) based on a sample of more than 10,000 Japanese workers. The questionnaire has demonstrated moderate reliability, high internal consistency, and its criterion validity has been assessed with respect to the Job Content Questionnaire (JCQ) and The National Institute for Occupational Safety and Health (NIOSH) [24].

The follow-up questionnaire was distributed 1 year after the baseline questionnaire was administered. Of the 5,310 participants who completed the baseline questionnaire, 3,811 successfully completed and returned the follow-up questionnaire, resulting in a follow-up rate of 71.8%. The follow-up questionnaire included questions relating to LBP, such as severity of LBP during the past year, length of sick-leave due to LBP, whether medical care was sought, pain duration, and onset pattern. LBP severity was assessed by the respondents themselves, using the same categories as those of the baseline questionnaire.

Ethical approval for the study was provided by the review board of the Japan Labour, Health and Welfare Organization. Informed consent was obtained in writing from all participants.

Data analysis

The outcome of interest was occurrence of persistent LBP during the 1-year follow-up period. In this study, persistent LBP was categorized as LBP interfering with work (grade 2 or grade 3), with disability lasting for longer than 3 months. Incidence was calculated for the participants who reported mild LBP (grade 1) during the past year at baseline. Participants were excluded from the analysis if they met any of the following criteria: a job change for reasons other than LBP; LBP due to a traffic accident; or LBP caused by a tumor, including metastasis, infection or fracture.

In addition to the compilation of simple, descriptive statistics, univariate and multivariate logistic regression analyses were used to explore risk factors associated with persistent LBP. Associations found by logistic regression analysis were summarized as odds ratios (ORs) with 95% confidence intervals (CIs). For the assessment of potential risk factors, crude ORs initially were estimated. Next, factors with P-values$<$0.1 were adjusted for individual factors, and also adjusted for individual factors and an ergonomic factor, in order to explore their potential risk factors. Factors with adjusted ORs that were statistically significant were considered to be potential risk factors. The following factors were used as adjusting factors because they are considered to be representative of individual and ergonomic factors: age, sex, obesity, smoking habits, education, and manual handling of objects [25–27]. Additionally, the above psychosocial risk factors were grouped by their correlations to explore multicollinearity, and then a statistically significant factor that had the highest adjusted ORs were selected from each group and applied to multivariate regression analysis. Statistical significance was assumed at the 5% level if the 95% CI did not overlap 1. All statistical calculations were carried out using the STATA 9.0 software package.

Results

Baseline characteristics of study participants

Of the 3,811 participants who responded to the 1-year follow-up questionnaires, 1,675 (excluding 43 who did not answer the question on LBP severity on their follow-up questionnaire) reported mild LBP during the past year at baseline and met the selection criteria. The mean age was 43.1 years (SD 10.1 years) and 1,342 (78.6%) were male. The mean BMI was 23.1 kg/m^2 (SD 3.4 kg/m^2). Of these participants, 1,165 (68.2%) were categorized as non-manual laborers; 147 (8.6%) as manual handlers of $<$ 20-kg objects; 338 (19.8%) as manual handlers of $\geq$ 20-kg objects or as caregivers; and 58 (3.4%) were lacking job description data. In each category, the most common occupations were office work in the non-manual laborer category; manufacturing/engineering in the manual handler of $<$ 20-kg objects category; and nurse in the manual handler of $\geq$ 20-kg objects or caregiver category.

The baseline characteristics of the 3,811 participants who provided follow-up data appeared to be not much different from those who did not. The mean (SD) ages were 42.9 (10.1) years and 38.0 (10.2) years, respectively, and the majority were male in both groups (80.6% and 82.8%, respectively). Those who completed the study had a mean (SD) BMI of 23.1 (3.3) while the values for dropouts were 22.9 (4.1). In the follow-up group (vs. the drop-out group), 78.6% (vs. 75.5%) were categorized as manually handling $<$ 20-kg objects or not manually handling any objects in their work, 17.8% (vs. 18.9%) manually handled $\geq$ 20-kg objects or were working as caregivers, and data were lacking for 3.6% (vs. 5.6%). In both groups, the most common occupational fields in the categories of "manual handling of $<$ 20-kg objects or not manually handling any objects", and "manual handling of $\geq$ 20-kg objects or working as a caregiver" were office worker and nurse, respectively.

Incidence of persistent LBP

Of the 1,675 eligible participants, 43 (2.6%) reported persistent LBP within the 1-year follow-up period. Of the 43 participants reporting persistent LBP, 76.7% had pain that persisted for longer than 6 months.

Association between persistent LBP and potential risk factors

Crude ORs for persistent LBP, their 95% CIs, and P-values are shown in Table S1. The "somatic symptoms" risk factor was associated with an approximately 2.5-fold higher risk of suffering from persistent LBP. Associations of persistent LBP, with about a 2-fold risk increase, were also found with the following 5 psychosocial factors: interpersonal stress at work, job satisfaction, depression, support from supervisors, and daily-life satisfaction factors. An approximately 2-fold risk increase was found for the following 2 factors: previous sick-leave due to LBP and family history of LBP with work disability. Of the ergonomic factors, 7 (manual handling of objects at work, frequent bending, twisting, lifting, or pushing, hours of desk work, and physical workload) were associated with about a 3- to 4-fold higher risk of developing persistent LBP. These 15 factors were chosen for multivariate logistic regressions, and the results are shown in Table 1. Most of the ergonomic factors were significant with the ORs adjusted for individual factors. Five factors from the BJSQ (interpersonal stress at work, job satisfaction, depression, somatic symptoms, and support from supervisors), as well as previous sick-leave due to LBP and family history of LBP with disability, remained statistically significant or almost significant by adjusted ORs. The magnitudes of adjusted ORs of these factors did not markedly change from our crude OR analyses. Among the 5 factors from the BJSQ, interpersonal stress at work, job satisfaction, and support from supervisors tended to correlate to each other, and depression and somatic symptoms tended to correlate to each other (Spearman's rho, data not shown). Additional multivariate regression analysis included job satisfaction and somatic symptoms from the BJSQ psychosocial factors and family history of LBP with disability, chosen by the statistical significance of the adjusted OR. As shown in Table 2, all of the factors remained statistically significant or almost significant in the multivariate analysis.

Discussion

Potential risk factors for people with LBP that could aggravate the condition and cause too much disability to work were explored in a cohort of urban Japanese workers. The incidence of persistent LBP developing from mild LBP was 2.6%. ORs adjusted for individual factors and an ergonomic factor (manual handling of objects) showed that low job satisfaction, lack of support from supervisors, interpersonal stress at work, depression, somatic symptoms, and a family history of LBP with disability were significant risk factors, and previous sick leave a nearly significant risk factor, for development of persistent from mild LBP. Our results indicate that these psychosocial factors are important in urban Japanese workers who have made the transition from mild to persistent LBP.

In this study, the definition of persistent LBP was disability longer than 3 months, and the index for disability was LBP interfering with work, with or without sick leave. In Western countries, 'absence from work' is often used as an outcome measurement for disability. The number of participants who were absent due to LBP (grade 3) was relatively small. Our previous international epidemiological study showed that taking sick leave due to musculoskeletal disorders, mostly LBP, appears to be less common among Japanese workers than British workers [28]. The lower percentage of absence due to LBP in Japanese workers compared to workers in European countries may be due to a difference in concerns about being absent, such as worries that it might affect employment, salary increases, or evaluations of work performance. In fact, the proportion of Japanese workers with disability irrespective of taking sick leave (sick leave defined as any unplanned absence from work) was approximately the same as the proportion of UK workers with sickness-related absences. Additionally, in another international cross-sectional study, the prevalence of disabling LBP varied markedly across countries, and the Japanese workers showed the lower prevalence than in other countries [29]. Therefore, when assessing Japanese workers, it seems appropriate to define LBP disability as LBP interfering with work, with or without sick leave.

Among the five factors from the BJSQ (low job satisfaction, little support from supervisors, interpersonal stress at work, depression, and somatic symptoms), low job satisfaction, little support from supervisors, and interpersonal stress at work tend to relate to each other, and depression and somatic symptoms tend to relate to each

Table 1. Adjusted odds ratios of the baseline factors for persistent low back pain (LBP) with work disability; factors with crude odds ratio P values<0.1.

Factors		%	OR Adjusted for individual factors[a]		OR Adjusted for individual factors and an ergonomic factor[b]	
			OR	95%CI	OR	95%CI
Previous sick leave due to LBP	No previous sick leave	76.5	1.00		1.00	
	Previous sick leave	23.5	1.92	0.99–3.74	1.94	0.98–3.86
Manual handling of materials at work	Manual handling of < 20-kg objects including desk work	79.5	1.00			
	Manual handling of ≥ 20-kg objects or working as a caregiver	20.5	2.70	1.98–8.67	-	-
Bending[c]	Infrequent	88.7	1.00			
	Frequent	11.3	3.45	1.54–7.72	-	-
Twisting[c]	Infrequent	94.6	1.00			
	Frequent	5.4	4.35	1.80–10.52	-	-
Lifting[c]	Infrequent	89.6	1.00			
	Frequent	10.4	2.81	1.18–6.66	-	-
Pushing[c]	Infrequent	95.2	1.00			
	Frequent	4.8	3.48	1.24–9.76	-	-
Hours of desk work[d]	< 6 hours per day	53.9	1.00		1.00	
	≥ 6 hours per day	46.1	0.45	0.23–0.88	0.66	0.31–1.40
Physical workload[e]	No stress	61.9	1.00		1.00	
	Stress	38.1	2.22	1.16–4.23	1.53	0.70–3.33
Interpersonal stress at work[e]	No stress	78.8	1.00		1.00	
	Stress	21.2	2.04	1.06–3.93	1.96	1.00–3.82
Job satisfaction[e]	Satisfied	77.3	1.00		1.00	
	Not satisfied	22.7	2.48	1.31–4.70	2.34	1.21–4.54
Depression[e]	Not feeling depressed	64.6	1.00		1.00	
	Depressed	35.4	2.09	1.10–3.99	1.92	1.00–3.69
Somatic symptoms[e]	No somatic symptoms	63.4	1.00		1.00	
	Somatic symptoms	36.6	2.99	1.55–5.75	2.78	1.44–5.40
Support from supervisors[e]	Support	74.0	1.00		1.00	
	No support	26.0	1.97	1.04–3.73	2.01	1.05–3.85
Daily-life satisfaction[e]	Satisfied	68.7	1.00		1.00	
	Not satisfied	31.3	1.81	0.97–3.40	1.61	0.84–3.08
Family history of LBP with disability	No LBP with disability	74.6	1.00		1.00	
	LBP with disability	25.4	2.02	1.07–3.81	1.98	1.04–3.78

OR: odds ratio, CI: confidence interval, LBP: low back pain
[a]Adjusted for age, gender, obesity, smoking habits, and education.
[b]Adjusted for age, gender, obesity, smoking habits, education, and manual handling of materials at work.
[c]Bending, twisting, lifting, and pushing: ≥ half of the day was considered frequent.
[d]Hours of desk work: longer than 6 hours per day was considered to be static posture.
[e]Work-related stress factors assessed with the brief job stress questionnaire: not feeling stressed, feeling stressed: the 5 original responses were reclassified into "not feeling stressed", where low, slightly low and moderate were combined, and "feeling stressed", where slightly high and high were combined.
doi:10.1371/journal.pone.0093924.t001

other. The first three factors (e.g., low job satisfaction) could be considered stressful conditions that directly and negatively affect the individual, and the latter two factors (e.g., depression) as symptoms of both physical and mental stress. Generally, the symptoms of somatization are headaches, neck and shoulder discomfort, dizziness, palpitations or shortness of breath, diarrhea or constipation, and back pain, and these symptoms are triggered by emotional discomfort and psychosocial distress [30]. Individuals with somatization often complain of pain in various locations, functional disturbance of various organ systems, and are depressed or overwhelmed by these symptoms. Patients falling into such a situation are usually said to suffer from functional somatic syndrome (FSS) [31,32]. Our results could suggest that workers with mild LBP, under frazzled, depressed, or somatizing conditions, accompanied by emotional discomfort and psychosocial distress (e.g., low job satisfaction, little social support from

Table 2. Multivariate-adjusted odds ratios for the persistent low back pain (LBP).

Factors		Adjusted OR[a]	95%CI	P value
Job satisfaction	Satisfied	1.00		
	Not satisfied	2.03	1.01–4.07	0.046
Somatic symptoms	No somatic symptoms	1.00		
	Somatic symptoms	2.46	1.25–4.83	0.009
Family history of LBP with disability	No LBP with disability	1.00		
	LBP with disability	2.00	1.03–3.88	0.042

OR: odds ratio, CI: confidence interval, LBP: low back pain.
[a]Adjusted for individual factors (age, gender, obesity, smoking habits, and education) and an ergonomic factor (manual handling).
doi:10.1371/journal.pone.0093924.t002

supervisors, and interpersonal stress at work), did not manifest disabling back pain as a symptom of FSS at baseline, but the pain became disabling during the following year.

A family history of persistent LBP was also suggested as a psychosocial risk factor in this analysis. Second-hand experience of LBP among people with whom a worker is in very close contact (families, friends, or partners) may make it easier to imagine how mild LBP transforms to persistent LBP. Previous research has revealed that some people can share another person's physical pain experience, in both emotional and sensory components, by just observing the other person's pain [33,34]. Family members, therefore, may provide reinforcement for sick behavior [35], even though these family members do not have had any disorders, such as back pain [36–39].

Psychosocial intervention has been reported to improve overall well-being, as well as reducing distress and physical complaints, in patients with LBP in Western countries [40]. This intervention is based on the hypothesis that psychosocial factors are associated with the transition to persistent LBP, and should be examined in future research studies in Japan.

Limitations of the current study should be mentioned. One is the fact that the majority of the subjects were males, and that a broad range of Japanese occupations was not represented. The study cohort was not a representative sample of the entire Japanese workers in urban areas; therefore, the generalizability of the findings may be limited. Secondly, although cognitive and emotional aspects of back pain are known to influence disability aggravation, some important psychosocial factors, such as the attitudes of health care providers, and catastrophizing and fear-avoidance beliefs, were not included in this analysis. This was because appropriate questionnaires were not available in the Japanese language. Future studies should include additional self-reported outcome measures, such as results of the Fear-Avoidance Belief Questionnaire (FABQ) [41,42] or the Tampa Scale of Kinesiophobia (TSK) [43,44], to assess the impact of these factors in Japanese workers. The Japanese versions of these questionnaires are now being developed.

Psychosocial factors are one of the most important risk factors for making the transition to persistent LBP from mild LBP in urban Japanese workers. In the future, preventive strategies for reducing persistent LBP in the workplace should deal not only with physical work demands, which is already well-understood, but potentially should incorporate psychosocial management techniques as well.

Supporting Information

Table S1 Crude odds ratios of the baseline factors for persistent low back pain (LBP) with work disability. OR: odds ratio, CI: confidence interval, BMI: body mass index, LBP: low back pain. [a] Obesity: BMI of ≥ 25 is defined as obesity in Japan. [b] Smoking habits: Brinkmann index of ≥ 400 was defined as heavy smoker, calculated from the total number of cigarettes smoked per day multiplied by duration of smoking in years [45]. [c] Working hours: ≥ 60 hours per week was assumed to be uncontrolled overtime. [d] Bending, twisting, lifting, and pushing: ≥ half of the day was considered frequent. [e] Hours of desk work: longer than 6 hours per day was considered as static posture. [f] Work-related stress factors assessed with the brief job stress questionnaire: not feeling stressed, feeling stressed: the 5 original responses were reclassified into "not feeling stressed", where low, slightly low and moderate were combined, and "feeling stressed", where slightly high and high were combined. [g] Monotonous task: feelings of monotony or boredom at work.
(DOC)

Author Contributions

Conceived and designed the experiments: K. Matsudaira HK K. Miyoshi. Performed the experiments: K. Matsudaira HK K. Miyoshi. Analyzed the data: K. Matsudaira TI KI. Wrote the paper: K. Matsudaira TI KI.

References

1. Vos T, Flaxman AD, Naghavi M, Lozano R, Michaud C, et al. (2010) Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990–2010: a systematic analysis for the Global Burden of Disease Study. Lancet 380: 2163–2196.
2. Ministry of Health, Labour and Welfare (2010) Survey of Living Conditions. Available: http://www.mhlw.go.jp/toukei/saikin/hw/k-tyosa/k-tyosa10/3-1.html. Accessed 2012 May 21.
3. Krismer M, van Tulder M (2007) Low back pain (non-specific). Best Practice & Research Clinical Rheumatology 21: 77–91.
4. Deyo RA, Rainville J, Kent DL (1992) What can the history and physical examination tell us about low back pain? JAMA 268: 760–765.
5. Schmidt CO, Raspe H, Pfingsten M, Hasenbring M, Basler HD, et al. (2007) Back pain in the German adult population: prevalence, severity, and sociodemographic correlates in a multiregional survey. Spine (Phila Pa 1976) 32: 2005–2011.
6. Walker BF, Muller R, Grant WD (2004) Low back pain in Australian adults: prevalence and associated disability. J Manipulative Physiol Ther 27:238–244.
7. Snook SH (2004) Work-related low back pain: secondary intervention. J Electromyogr Kinesiol 14: 153–160.
8. Maetzel A, Li L (2002) The economic burden of low back pain: a review of studies published between 1996 and 2001. Best Pract Res Clin Rheumatol 16: 23–30.
9. Waddell G, Burton AK (2001) Occupational health guidelines for the management of low back pain at work: evidence review. Occup Med 51: 124–135.

10. Papageorgiou AC, Croft PR, Thomas E, Ferry S, Jayson MI, et al. (1996) Influence of previous pain experience on the episode incident of low back pain: results the South Manchester Back Pain Study. Pain 66: 181–185.
11. Currie SR, Wang JL (2004) Chronic back pain and major depression in the general Canadian population. Pain 107: 54–60.
12. Waddell G (2004) Social interactions. In: G Waddell, ed. The Back Pain Revolution. 2nd ed. Edinburgh: Chuechill-Livingstone: 241–63.
13. Matsudaira K, Konishi H, Miyoshi K, Isomura T, Takeshita K, et al. (2012) Potential risk factors for new-onset of back pain disability in Japanese workers: findings from the Japan epidemiological research of occupation-related back pain (JOB) study. Spine (Phila Pa 1976) 37: 1324–1333.
14. Von Korff M, Ormel J, Keefe FJ, Dworkin SF (1992) Grading the severity of chronic pain. Pain 50: 133–149.
15. Muto S, Muto T, Seo A, Yoshida T, Taoda K, et al. (2006) Prevalence of and risk factors for low back pain among staffs in schools for physically and mentally handicapped children. Ind Health 44: 123–127.
16. Kawakami N, Kobayashi Y, Takao S, Tsutsumi A (2005) Effects of web-based supervisor training on supervisor support and psychological distress among workers: a randomized controlled trial. Prev Med 41: 471–478.
17. Kawakami N, Kobayashi F, Araki S, Haratani T, Furui H (1995) Assessment of job stress dimensions based on the job demands- control model of employees of telecommunication and electric power companies in Japan: reliability and validity of the Japanese version of the Job Content Questionnaire. Int J Behav Med 2: 358–375.
18. Haratani T, Kawakami N, Araki S (1993) Reliability and validity of the Japanese version of NIOSH Generic Job Questionnaire. Sangyo Igaku (Jpn J Ind Med) 35(suppl): S214 (in Japanese).
19. Yokoyama K, Araki S, Kawakami N, Takeshita T (1990) Production of the Japanese edition of profile of mood states (POMS): assessment of reliability and validity (in Japanese). Nippon Koshu Eisei Zasshi 37: 913–918.
20. Shima S, Shikano T, Kitamura T, Asai M (1985) New self-rating scales for depression. Clinical Psychiatry 27: 717–723 (in Japanese).
21. Spielberger CD, Gorsuch RL, lushene RE (1970) STAI Manual. Palo Alto: Consulting Psychologist Press.
22. Isaac M, Tacchini G, Janca A (1994) Screener for somatoform disorders (SSD). Geneva: World Health Organization.
23. Ono Y, Yoshimura K, Yamauchi K, Momose T, Mizushima H, et al. (1996) Psychological well-being and ill-being: WHO Subjective Well-being Inventory (SUBI) (in Japanese). Jpn J Stress Sci 10: 273–278.
24. Shimomitsu T, Odagiri Y (2004) The brief job stress questionnaire (in Japanese). Occup Mental Health 12: 25–36.
25. Linton SJ (2001) Occupational Psychological Factors Increase the Risk for Back Pain: a systematic review. J Occup Rehabil 11: 53–66.
26. Bernard BP (1997) Musculoskeletal disorders and workplace factors: a critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back. Cincinnati: U.S. Department of Health and Human Services. 590p.
27. Hoogendoorn WE, van Poppel MNM, Bongers PM, Koes BW, Bouter LM (2000) Systematic review of psychosocial factors at work and private life as risk factors for back pain. Spine 25: 2114–2125.
28. Matsudaira K, Palmer KT, Reading I, Hirai M, Yoshimura N, et al. (2011) Prevalence and correlates of regional pain and associated disability in Japanese workers. Occup Environ Med 68: 191–196.
29. Coggon D, Ntani G, Palmer KT, Felli VE, Harari R, et al. (2013) Disabling musculoskeletal pain in working populations: is it the job, the person, or the culture? Pain 154: 856–863.
30. Kaplan C, Lipkin M Jr, Gordon GH (1988) Somatization in primary care: patients with unexplained and vexing medical complaints. J Gen Intern Med 3: 177–190.
31. Barsky AJ, Borus JF (1999) Functional somatic syndromes. Ann Intern Med 130: 910–921.
32. Henningsen P, Zipfel S, Herzog W (2007) Management of functional somatic syndromes. Lancet 369: 946–955.
33. Crook J, Milner R, Schultz IZ, Stringer B (2002) Determinants of occupational disability following a low back injury: a critical review of the literature. J Occup Rehabil 12: 277–295.
34. Shaw WS, Pransky G, Fitzgerald TE (2001) Early prognosis for low back disability: intervention strategies for health care providers. Disabil Rehabil 23: 815–828.
35. Osborn J, Derbyshire SW (2010) Pain sensation evoked by observing injury in others. Pain 148: 268–274.
36. Linton SJ (2000) Psychological risk factors for neck and back pain. In: Nachemson AJ, Jonsson E, editors. Neck and Back Pain: The scientific evidence of causes, diagnosis and treatment. Philadelphia: Lippincot Williams & Wilkins. pp. 57–78.
37. Ogino Y, Nemoto H, Inui K, Saito S, Kakigi R, et al. (2007) Inner experience of pain: imagination of pain while viewing images showing painful events forms subjective pain representation in human brain. Cereb Cortex 17:1139–1146.
38. Lynch AM, Kashikar-Zuck S, Goldschneider KR, Jones BA (2006) Psychosocial risks for disability in children with chronic back pain. J Pain 7: 244–251.
39. Evans S, Tsao JC, Lu Q, Myers C, Suresh J, et al. (2008) Parent-child pain relationships from a psychosocial perspective: a review of the literature. J Pain Manag 1: 237–246.
40. Williams RM, Westmorland MG, Lin CA, Schmuck G, Creen M (2007) Effectiveness of workplace rehabilitation interventions in the treatment of work-related low back pain: a systematic review. Disabil Rehabil 29: 607–624.
41. Westman AE, Boersma K, Leppert J, Linton SJ (2011) Fear-avoidance beliefs, catastrophizing, and distress: a longitudinal subgroup analysis on patients with musculoskeletal pain. Clin J Pain. 27: 567–577.
42. Waddell G, Newton M, Henderson I, Somerville D, Main CJ (1993) A fear-avoidance beliefs questionnaire (FABQ) and the role of fear-avoidance beliefs in chronic low back pain and disability. Pain 52: 157–168.
43. Miller RP, Kori SH, Todd DD (1991) The Tampa Scale: a measure of kinisophobia. Clin J Pain 7: 51–52 (Data unpublished).
44. Kori KS, Miller RP, Todd DD (1990) Kinesiophobia: a new view of chronic pain behavior. Pain Manag 3: 35–43.
45. Brinkman GL, Coates O (1963) The effect of bronchitis, smoking and occupation on ventilation. Ann Rev Respir Dis 87: 684–693.

J Orthop Sci (2014) 19:26–32
DOI 10.1007/s00776-013-0471-5

ORIGINAL ARTICLE

Psychometric properties of the Japanese version of the Fear-Avoidance Beliefs Questionnaire (FABQ)

Ko Matsudaira · Norimasa Kikuchi · Aya Murakami · Tatsuya Isomura

Received: 17 April 2013 / Accepted: 4 September 2013 / Published online: 5 October 2013

Abstract
Background The Fear-Avoidance Beliefs Questionnaire (FABQ) is useful for measuring fear-avoidance beliefs in patients with low back pain (LBP); however, no psychometrically validated Japanese version is available. The objective of this study was to evaluate reliability and validity of the Japanese version of the FABQ for use with Japanese workers with LBP.
Methods This was conducted as a web-based survey. Both confirmatory and exploratory factor analysis were performed to examine domain structure of the Japanese version of the FABQ. For reliability, internal consistency was assessed with Cronbach's alpha coefficient. For concurrent validity, correlation coefficients between the FABQ and the Pain Catastrophizing Scale (PCS) were calculated. For known-group validity, the relationship between FABQ score and clinical variables such as pain and depression was examined.
Results Analyses were based on responses of 1,786 adult Japanese workers with LBP. Factor analysis using the principal factor method with promax rotation revealed two factors, work and physical activity, in accordance with the domain structure of the original version of the scale. For reliability, acceptable internal consistency was demonstrated with Cronbach's alpha coefficient of 0.882 and 0.783 for each subscale. For concurrent validity, significantly moderate correlations were demonstrated between FABQ subscales and PCS subscales ($r = 0.30$–0.39). For known-group validity, as hypothesized, significantly higher FABQ subscale scores were observed in workers who had stronger pain, who experienced routine work disability with sick leave, who experienced recurrence of LBP, and who had depressed mood.
Conclusions This analysis showed that the Japanese version of the FABQ is psychometrically reliable and valid to detect fear-avoidance beliefs in Japanese workers with LBP.

K. Matsudaira (✉)
Clinical Research Center for Occupational Musculoskeletal Disorders, Kanto Rosai Hospital, 1-1 Kizukisumiyoshicho, Nakahara-ku, Kawasaki 211-8510, Japan
e-mail: kohart801@gmail.com

N. Kikuchi · A. Murakami · T. Isomura
CLINICAL STUDY SUPPORT, Inc., Nagoya, Japan

Introduction

Many patients with low back pain (LBP) experience fear of future pain. Patients with LBP who experience strong pain may avoid certain movements or physical activities because of exaggerated fears that pain will result in more functional restriction [1]. The repeating cycle of pain-related fear and avoidance behaviors can continue. Avoidance of physical activities based on fear-avoidance beliefs leads to further avoidance [2]. Little evidence has shown that avoidance behavior reduces chronic LBP either on a short- or long-term basis. Rather, fear-avoidance beliefs have been shown to play a contributing role in the development of long-term disability [3–5]. The Global Burden of Disease (GBD) studies done in 1990 and 2000 demonstrate that LBP is one of the leading specific causes of years living with disability (years of life lived in less than ideal health) [6]. A low level of fear avoidance is the most useful item for predicting earlier recovery [7, 8]. Avoidance of pain-inducing activities can result in reduced muscle strength and flexibility, which may partly contribute to a delay in recovery. Thus, chronic pain and disability may be perpetuated by fear-avoidance beliefs and behaviors.

The Fear Avoidance Belief Questionnaire (FABQ), introduced by Waddell et al. [9], is a useful measure for assessing fear-avoidance beliefs in patients with LBP. The Multinational Musculoskeletal Inception Cohort Study Statement proposed that fear avoidance should be included in the core set of factors to be measured for prospective cohorts of patients with LBP, and the FABQ was recommended as the appropriate measure to detect fear-avoidance beliefs [10]. This 16-item self-report questionnaire can assess patients' beliefs about how physical activity and work affect their present LBP. Factor analysis in the development of the original version revealed two subscales: work (seven items) and physical activity (four items). The other five items are not included in the score calculation. Patients rate their agreement with each statement on a 7-point Likert scale (0 for completely disagree, 3 for unsure, 6 for completely agree). A subscale score is calculated by the simple sum of attribute item scores. Scores range 0–42 for the work subscale and 0–24 for the physical activity subscale. A higher score indicates stronger fear-avoidance beliefs or behaviors.

The FABQ was originally developed in English, and its reliability and validity have been demonstrated in British patients with LBP and/or sciatica [9]. It has been successfully translated into several languages and is widely used for evaluation in clinical studies [11–16]. However, a psychometrically validated Japanese version of the FABQ is not available. Therefore, we translated the original English version into Japanese and validated it linguistically, aiming to introduce the FABQ in Japan [17]. In this study, we performed a psychometric assessment of the Japanese version of the FABQ to evaluate its reliability and validity for use in Japanese patients with LBP.

Materials and methods

Validation sample

The data subset used in this psychometric testing was derived from an Internet survey used to collect information on Japanese people, including prevalence of LBP, work-related ergonomic characteristics, and attitudes/beliefs about LBP [18]. An Internet research company registered 1.8 million individuals who were 20–79 years old as monitors. These monitors were stratified by sex and age, and 1,063,083 monitors were randomly selected in accordance with Japanese demographic composition and invited to participate in research on LBP by an e-mail containing a link to the survey. Double registration as a monitor was prevented by checking e-mail addresses and by blocking access to the questionnaire once the responder completed the survey. Among the selected monitors, 77,709 individuals completed the survey, which resulted in a response rate of 7.31 %. Individuals whose reported age was <20 or >79 were excluded when calculating LBP prevalence, resulting in 65,496 participants. Of these, 3,220 Japanese workers who reported that they had experienced LBP within the previous 4 weeks were contacted by e-mail and invited to complete an online questionnaire. Under the assumption of a relatively low response rate (around 30 %), our goal was to obtain at least 1,000 completed questionnaires, and the survey was closed on the day the number of respondents exceeded 1,000.

Based on the consensus approach to back pain definition proposed by Dionne et al., LBP was defined as pain localized between the costal margin and the inferior gluteal folds that lasted for more than a day at any time during the past 4 weeks [19]. Pain associated only with menstrual periods, pregnancy, or during a course of a feverish illness was not included. A definition of LBP and a diagram of the affected area were provided within the questionnaire.

The questionnaire included the Japanese version of the Pain Catastrophizing Scale (PCS) [20, 21], a 13-item scale used to measure negative attitudes toward pain, involving rumination, helplessness, and magnification. The reliability and validity of the Japanese version were previously confirmed [21]. Total PCS scores range from 0 (no catastrophizing) to 52 (severe catastrophizing). The Mental Health (MH) domain of the Short-Form Health Survey of 36 questions (SF-36) and an 11-point numerical rating scale (NRS) were also included to assess MH and pain, respectively. The survey was approved by the medical/ethics review board of the Japan Labour Health and Welfare Organization. Personal identifiable information, including name, phone number, and permanent address, were not collected. Due to the nature of this study (web-based survey), no written informed consent was obtained; however, receiving an answered questionnaire was considered evidence of consent.

Data analysis

Demographic characteristics of the validation sample were summarized with simple descriptive analysis. In the item analysis, the percentage of missing responses was examined for each item. We also examined whether each item's response distribution was strongly skewed, that is, whether it had a floor or ceiling effect of $\geq$60 %. For construct validity, confirmatory factor analysis (CFA) using the principal factor method with a promax rotation was performed on the original two-factor model. Both Goodness of Fit Index (GFI) and Adjusted GFI (AGFI) of $\geq$0.9 are considered a reflection of good fit. Exploratory factor analysis (EFA) was also used as necessary. For convergent and discriminant validity, multitrait analysis was used. For each item, if the correlation coefficient between the score of the individual item and the subscale score to which that item was attributed (subscale score except for that item) is not extremely low, convergent validity is judged as acceptable. Also, for each item, if the correlation coefficient between the score of the individual item and the subscale score to which that item is attributed is greater than the correlation coefficients between the score of that item and the other subscale score to which that item is not attributed, then discriminant validity is judged as acceptable. With regard to internal consistency, the homogeneity of the items in each subscale was evaluated using Cronbach's alpha statistic. Cronbach's alpha coefficient of 0.7 or higher for both subscales is needed to claim that the FABQ is internally consistent [22]. Concurrent validity was evaluated using Spearman's rank correlation coefficient with the PCS. According to the criterion of correlation strength in the psychometric validation proposed by Cohen, the correlation coefficient was judged as follows: 0.1, weak correlation; 0.3, medium correlation; and 0.5, strong correlation [23]. For the known-group validity, relationships between selected variables and subscale scores were examined using the t test or analysis of variance (ANOVA), depending on the number of categories in a selected variable. If a statistically significant difference was found with ANOVA, then Tukey–Kramer multiple comparison was used to identify specific differences between pairs of groups. We hypothesized that workers who met the following attributes would show significantly higher FABQ scores: (1) workers with greater pain, (2) workers who experienced work disability with sick leave, (3) workers with more episodes of LBP, and (4) workers with depressed mood. In terms of pain, workers were categorized by the degree of pain as assessed using an NRS (0 = no pain to 10 = worst pain imaginable). The group in the first tertile was categorized as having slight pain, the second tertile as having moderate pain, and the third tertile as having severe pain. With regards to sick leave, if workers had to miss work due to LBP at least 1 day during 4 weeks, it is considered sick leave. In terms of the number of LBP episodes, if workers experience LBP after at least 1 month of being pain free, it is considered recurrence [24]. Depressed mood was assessed using the SF-36 Mental Health domain [25, 26]. A score of $\leq$52 was considered as depressed mood (range 0–100, low scores indicate more psychological distress) [27]. All statistical tests were two-tailed, and the level of significance was set at 0.05. Statistical calculations were performed using SAS version 9.2 (SAS Institute, Cary, NC, USA).

Table 1 Clinical characteristics of the patient sample used for psychometric validation of the Japanese Fear-Avoidance Beliefs Questionnaire ($N = 1,786$)

Characteristics	Statistics	(%)
Sex		
Male	900	(50.4)
Age, year		
20–39	603	(33.8)
40–59	621	(34.8)
≥60	562	(31.5)
Educational background		
College/technical college/high school/ junior high	951	(53.2)
University or higher	825	(46.2)
Not applicable	10	(0.6)
Pain (NRS), mean ± SD	2.9 ± 2.3	
Presence of disability		
No	544	(30.5)
Yes with no sick leave	801	(44.8)
Yes with sick leave	441	(24.7)
Job category		
White collar	687	(38.5)
Blue collar	273	(15.3)
Other	826	(46.2)
FABQ score, mean ± SD		
Work subscale	16.3 ± 9.8	
Physical activity subscale	14.9 ± 4.7	
PCS score, mean ± SD	24.6 ± 10.9	
MH subscale score in SF-36, mean ± SD	55.1 ± 20.9	

Unless otherwise specified, n (%) is shown

NRS numerical rating scale (0–10, higher score indicates greater pain), *FABQ* Fear-Avoidance Belief Questionnaire (0–42 for work subscale and 0–24 for physical activity subscale. A higher score indicates stronger fear-avoidance beliefs or behaviors), *PCS* Pain Catastrophizing Scale (0–52, a higher score indicates severe catastrophizing), *MH* Mental Health (0–100, a lower score indicates more psychological distress), *SF-36* Short-Form Health Survey with 36 questions, *SD* standard deviation

Results

Patient background

Overall, 1,786 workers were analyzed, and their characteristics are shown in Table 1. Mean age was 48.7 years, and 50.4 % were men. FABQ scores [mean ± standard deviation (SD)] were 16.3 ± 9.8 for the work subscale and 14.9 ± 4.7 for the physical activity subscale. Scores in the PCS and MH of the SF-36 were 24.6 ± 10.9 and 55.1 ± 20.9, respectively.

Item analysis

There was no missing response in any item. Neither floor nor ceiling responses were observed in the distribution of responses, although skewed distribution was found in items 8, 15, and 16 (responses for completely disagree were 47.9, 48.6, and 55.2 %, respectively).

Factor analysis

CFA was performed on the original two-factor model, and GFI and AGFI were 0.84 and 0.76, respectively, indicating that there was no evidence of good fit. Thus, further assessment was performed using EFA with promax rotation. As a result, the eigenvalue was >1 with the two-factor model (i.e., 1.36), and all items were clearly regressed to the same factors as the original version, with factor-loading values >0.4 (Table 2). In addition, the result of multitrait analysis demonstrated satisfactory convergent and discriminant validity (Table 3). For these reasons, we consequently adopted the two-factor model. Also, no floor/ceiling effects were observed in the subscales (9.7 and 1.0 % for the work subscale; 1.5 and 5.2 % for the physical activity subscale).

Reliability

Cronbach's alpha coefficient was 0.882 for the work subscale and 0.783 for the physical activity subscale, indicating sufficient internal consistency.

Concurrent validity

Correlation coefficients between FABQ subscales and the PCS were calculated to examine concurrent validity. The work subscale moderately correlated with the PCS total score, the helplessness subscale, and the magnification subscale ($r = 0.38$, 0.39, and 0.34, respectively; $P < 0.0001$ for all). The physical activity subscale moderately correlated with the PCS total score, the rumination subscale, and the magnification subscale ($r = 0.36$, 0.36, and 0.30, respectively; $P < 0.0001$ for all).

Known-group validity

The relationship with variables that may affect the FABQ score was examined. As hypothesized, significantly higher FABQ subscale scores were observed in workers with stronger pain, workers who experienced work disability with sick leave, workers who experienced recurrence of LBP, and workers with depressed mood (Fig. 1).

Table 2 Rotated factor pattern (standardized regression coefficient)

Item	Factor 1	Factor 2
Factor 1: fear-avoidance beliefs about work		
6 My pain was caused by my work or by an accident at work	0.611	−0.005
7 My work aggravated my pain	0.770	0.023
9 My work is too heavy for me	0.760	−0.041
10 My work makes or would make my pain worse	0.904	−0.002
11 My work might harm my back	0.884	0.019
12 I should not do my normal work with my present pain	0.669	0.087
15 I do not think that I will be back to my normal work within 3 months	0.444	0.014
Factor 2: fear-avoidance beliefs about physical activity		
2 Physical activity makes my pain worse	0.017	0.799
3 Physical activity might harm my back	0.013	0.843
4 I should not do physical activities which (might) make my pain worse	−0.009	0.633
5 I cannot do physical activities which (might) make my pain worse	0.028	0.493

Table 3 Convergent and discriminant validity: correlation coefficients for question items and domain score (Spearman's correlation)

Item	Factor 1	Factor 2
Factor 1: fear-avoidance beliefs about work		
6 My pain was caused by my work or by an accident at work	0.565	0.217
7 My work aggravated my pain	0.720	0.306
9 My work is too heavy for me	0.711	0.230
10 My work makes or would make my pain worse	0.786	0.328
11 My work might harm my back	0.771	0.338
12 I should not do my normal work with my present pain	0.659	0.336
15 I do not think that I will be back to my normal work within 3 months	0.417	0.166
Factor 2: fear-avoidance beliefs about physical activity		
2 Physical activity makes my pain worse	0.326	0.577
3 Physical activity might harm my back	0.335	0.625
4 I should not do physical activities which (might) make my pain worse	0.228	0.563
5 I cannot do physical activities which (might) make my pain worse	0.233	0.416

Subscale scores were computed excluding the scores for items within a factor

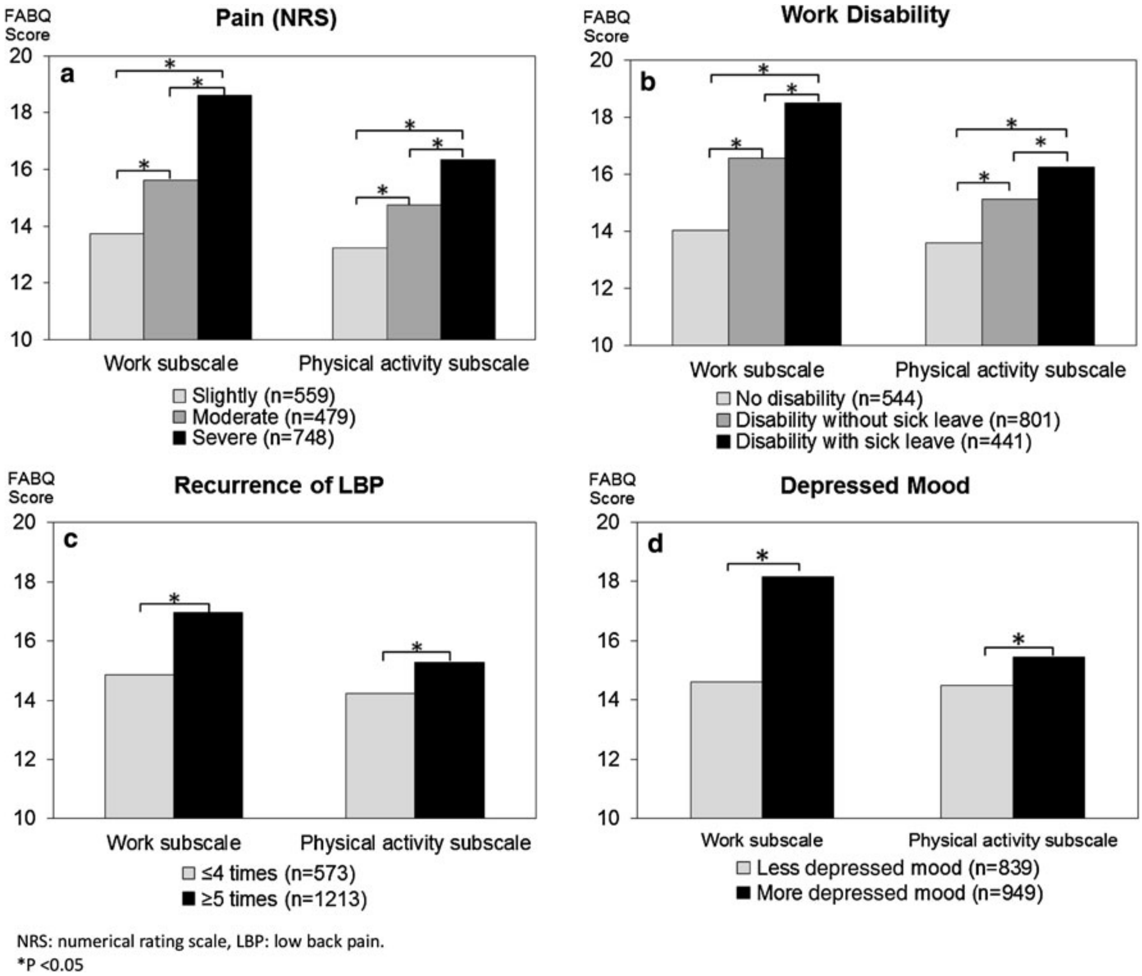

Fig. 1 Known-group validity: Fear-Avoidance Beliefs Questionnaire scores and associated variables: *P* values were calculated by Tukey–Kramer method for pain and routine work disability, and the *t* test was used to evaluate recurrence of low back pain (LBP) and depression

Discussion

Before the analysis performed in this study, we proposed a linguistically validated Japanese version of the FABQ [17], which was assured by following a standardized manner for developing a translated questionnaire [28]. In the study reported here, we assessed its psychometric properties. In the factor analysis conducted in a confirmatory manner, goodness of fit indicators did not satisfy the preset level. However, EFA revealed a two-factor solution consistent with the original questionnaire. In general, it is preferable that a translated version of a specific questionnaire maintains the same domain structure as the original version to enable comparison of data derived from different translated versions. Taking this into account, a two-factor model of the FABQ (work and physical activity subscales) was finally adopted in the Japanese version. Our decision in selecting the two-factor model was supported by the fact that reliability of the measure was demonstrated. As an index to assess reliability, a sufficient internal consistency with Cronbach's alpha statistic of 0.882 and 0.783, respectively, for the subscales was demonstrated. Internal consistency in the Japanese version was considered sufficient to be in agreement with the original version (Cronbach's alpha of 0.88 and 0.77) [9].

For known-group validity, as hypothesized, relevance was observed between FABQ score and variables that might affect the scores, including the degree of pain, work disability with sick leave, recurrence of LBP, and depressed mood. Similarly, in the development of the original version, significant correlations of FABQ were observed for pain severity ($r = 0.23$ for the work subscale), work loss in the past year ($r = 0.55$ for the work subscale, 0.23 for the physical activity subscale), and depressive symptoms ($r = 0.41$ and 0.34, respectively) [9].

Avoidance behavior led by fear and avoidance beliefs in patients with LBP contributes to the development of chronic disability. In fact, fear-avoidance behavior was shown to be an important risk factor for chronicity. Thus, encouraging patients to change their beliefs and behaviors has become more important in managing LBP, especially in the early phase. In recent guidelines for managing nonspecific, acute LBP, continuing normal daily activity is recommended and bed rest is discouraged [29]. To help reduce pain-related fear, it is important to focus on educating patients that pain is a common condition and is self-manageable, along with gradual exposure to activities, rather than on imaging findings leading to the development of fear-avoidance behavior. The FABQ enables clinicians to detect patient fear-avoidance beliefs and helps to establish an effective management program to prevent chronic LBP on an individual basis.

Limitations of this study should be noted. The use of the Internet to recruit participants could have contributed to selection bias, although the large sample size that this method allowed is a major strength of this study. However, we must also consider the issue of sample representativeness in this study. Our validation population might not represent a wide range of workers throughout the nation. Workers who can access the Internet might represent a particular socioeconomic status, such as being possibly wealthier, better educated, or relatively younger. We decided to recruit participants using the Internet, taking into account both costs and feasibility. Our strategy may invite criticism regarding generalizability of the results. Although results demonstrating the sufficient psychometric properties of the Japanese version of the FABQ as a measure might partly support the adequacy of the sample, it is still possible that good psychometric properties could have been demonstrated in an unrepresentative sample. Concerning the use of online questionnaires, the comparability of online testing to paper and pencil forms in regards to psychometric properties has been demonstrated [30, 31]. It should be noted that test–retest reliability over certain time intervals remains unknown. Also, responsiveness cannot be assessed in this study due to the cross-sectional nature of the data. Future studies would be helpful to assess the test–retest reliability and responsiveness of the Japanese version of the FABQ.

Results of the analysis presented here show that the Japanese version of the FABQ is psychometrically reliable and valid as a measure to detect fear-avoidance beliefs in a Japanese population with LBP. The Japanese version of the FABQ has the same domain structure as the original version (work and physical activity subscales), enabling comparisons with data derived using the original version.

Acknowledgments This study was supported by the Dissemination Project on the 13 Fields of Occupational Injuries and Illness of the Japan Labor Health and Welfare Organization.

Conflict of interest None.

References

1. Leeuw M, Goossens ME, Linton SJ, Crombez G, Boersma K, Vlaeyen JW. The fear-avoidance model of musculoskeletal pain: current state of scientific evidence. J Behav Med. 2007;30:77–94.
2. Vowles KE, Gross RT. Work-related beliefs about injury and physical capability for work in individuals with chronic pain. Pain. 2003;101:291–8.
3. Fritz JM, George SZ, Delitto A. The role of fear-avoidance beliefs in acute low back pain: relationships with current and future disability and work status. Pain. 2001;94:7–15.
4. Vlaeyen JW, de Jong J, Geilen M, Heuts PH, van Breukelen G. The treatment of fear of movement/(re)injury in chronic low back pain: further evidence of the effectiveness of exposure in vivo. Clin J Pain. 2002;18:251–61.
5. Al-Obaidi SM, Beattie P, Al-Zoabi B, Al-Wekeel S. The relationship of anticipated pain and fear avoidance beliefs to outcome in patients with chronic low back pain who are not receiving workers' compensation. Spine. 2005;30:1051–7.
6. Vos T, Flaxman AD, Naghavi M, Lozano R, Michaud C, Ezzati M, Shibuya K, Salomon JA, Abdalla S, Aboyans V, Abraham J, Ackerman I, Aggarwal R, Ahn SY, Ali MK, Alvarado M, Anderson HR, Anderson LM, Andrews KG, Atkinson C, Baddour LM, Bahalim AN, Barker-Collo S, Barrero LH, Bartels DH, Basáñez MG, Baxter A, Bell ML, Benjamin EJ, Bennett D, Bernabé E, Bhalla K, Bhandari B, Bikbov B, Bin Abdulhak A, Birbeck G, Black JA, Blencowe H, Blore JD, Blyth F, Bolliger I, Bonaventure A, Boufous S, Bourne R, Boussinesq M, Braithwaite T, Brayne C, Bridgett L, Brooker S, Brooks P, Brugha TS, Bryan-Hancock C, Bucello C, Buchbinder R, Buckle G, Budke CM, Burch M, Burney P, Burstein R, Calabria B, Campbell B, Canter CE, Carabin H, Carapetis J, Carmona L, Cella C, Charlson F, Chen H, Cheng AT, Chou D, Chugh SS, Coffeng LE, Colan SD, Colquhoun S, Colson KE, Condon J, Connor MD, Cooper LT, Corriere M, Cortinovis M, de Vaccaro KC, Couser W, Cowie BC, Criqui MH, Cross M, Dabhadkar KC, Dahiya M, Dahodwala N, Damsere-Derry J, Danaei G, Davis A, De Leo D, Degenhardt L, Dellavalle R, Delossantos A, Denenberg J, Derrett S, Des Jarlais DC, Dharmaratne SD, Dherani M, Diaz-Torne C, Dolk H, Dorsey ER, Driscoll T, Duber H, Ebel B, Edmond K, Elbaz A, Ali SE, Erskine H, Erwin PJ, Espindola P, Ewoigbokhan SE, Farzadfar F, Feigin V, Felson DT, Ferrari A, Ferri CP, Fèvre EM, Finucane MM, Flaxman S, Flood L, Foreman K, Forouzanfar MH, Fowkes FG, Franklin R, Fransen M, Freeman MK, Gabbe BJ, Gabriel SE, Gakidou E, Ganatra HA, Garcia B, Gaspari F, Gillum RF, Gmel G, Gosselin R, Grainger R, Groeger J, Guillemin F, Gunnell D, Gupta R, Haagsma J, Hagan H, Halasa YA, Hall W, Haring D, Haro JM, Harrison JE, Havmoeller R, Hay RJ, Higashi H, Hill C, Hoen B, Hoffman H, Hotez PJ, Hoy D, Huang JJ, Ibeanusi SE, Jacobsen KH, James SL, Jarvis D, Jasrasaria R, Jayaraman S, Johns N, Jonas JB, Karthikeyan G, Kassebaum N, Kawakami N, Keren A, Khoo JP, King CH, Knowlton LM, Kobusingye O, Koranteng A, Krishnamurthi R, Lalloo R, Laslett LL, Lathlean T, Leasher JL, Lee YY, Leigh J, Lim SS, Limb E, Lin JK, Lipnick M, Lipshultz SE, Liu W, Loane M, Ohno SL, Lyons R, Ma J, Mabweijano J, MacIntyre MF, Malekzadeh R, Mallinger L, Manivannan S, Marcenes W, March L, Margolis DJ, Marks GB, Marks R, Matsumori A, Matzopoulos R, Mayosi BM, McAnulty JH, McDermott MM, McGill N, McGrath J, Medina-Mora ME, Meltzer M, Mensah GA, Merriman TR, Meyer AC, Miglioli V, Miller M, Miller TR, Mitchell PB, Mocumbi AO, Moffitt TE, Mokdad AA, Monasta L, Montico M, Moradi-Lakeh M, Moran A, Morawska L, Mori R, Murdoch ME, Mwaniki MK, Naidoo K, Nair MN, Naldi L, Narayan KM, Nelson PK, Nelson RG, Nevitt MC, Newton CR, Nolte S, Norman P, Norman R, O'Donnell M,

O'Hanlon S, Olives C, Omer SB, Ortblad K, Osborne R, Ozgediz D, Page A, Pahari B, Pandian JD, Rivero AP, Patten SB, Pearce N, Padilla RP, Perez-Ruiz F, Perico N, Pesudovs K, Phillips D, Phillips MR, Pierce K, Pion S, Polanczyk GV, Polinder S, Pope CA 3rd, Popova S, Porrini E, Pourmalek F, Prince M, Pullan RL, Ramaiah KD, Ranganathan D, Razavi H, Regan M, Rehm JT, Rein DB, Remuzzi G, Richardson K, Rivara FP, Roberts T, Robinson C, De Leòn FR, Ronfani L, Room R, Rosenfeld LC, Rushton L, Sacco RL, Saha S, Sampson U, Sanchez-Riera L, Sanman E, Schwebel DC, Scott JG, Segui-Gomez M, Shahraz S, Shepard DS, Shin H, Shivakoti R, Singh D, Singh GM, Singh JA, Singleton J, Sleet DA, Sliwa K, Smith E, Smith JL, Stapelberg NJ, Steer A, Steiner T, Stolk WA, Stovner LJ, Sudfeld C, Syed S, Tamburlini G, Tavakkoli M, Taylor HR, Taylor JA, Taylor WJ, Thomas B, Thomson WM, Thurston GD, Tleyjeh IM, Tonelli M, Towbin JA, Truelsen T, Tsilimbaris MK, Ubeda C, Undurraga EA, van der Werf MJ, van Os J, Vavilala MS, Venketasubramanian N, Wang M, Wang W, Watt K, Weatherall DJ, Weinstock MA, Weintraub R, Weisskopf MG, Weissman MM, White RA, Whiteford H, Wiersma ST, Wilkinson JD, Williams HC, Williams SR, Witt E, Wolfe F, Woolf AD, Wulf S, Yeh PH, Zaidi AK, Zheng ZJ, Zonies D, Lopez AD, Murray CJ, AlMazroa MA, Memish ZA. Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet 2012; 380:2163-96.

7. Klenerman L, Slade PD, Stanley IM, Pennie B, Reilly JP, Atchison LE, Troup JD, Rose MJ. The prediction of chronicity in patients with an acute attack of low back pain in a general practice setting. Spine. 1995;20:478–84.
8. Chou R, Shekelle P. Will this patient develop persistent disabling low back pain? JAMA. 2010;303:1295–302.
9. Waddell G, Newton M, Henderson I, Somerville D, Main CJ. A fear-avoidance beliefs questionnaire (FABQ) and the role of fear-avoidance beliefs in chronic low back pain and disability. Pain. 1993;52:157–68.
10. Pincus T, Santos R, Breen A, Burton AK, Underwood M. Multinational Musculoskeletal Inception Cohort Study Collaboration. A review and proposal for a core set of factors for prospective cohorts in low back pain: a consensus statement. Arthritis Rheum. 2008;59:14–24.
11. Pfingsten M, Kröner-Herwig B, Leibing E, Kronshage U, Hildebrandt J. Validation of the German version of the fear-avoidance beliefs questionnaire (FABQ). Eur J Pain. 2000;4:259–66.
12. Chaory K, Fayad F, Rannou F, Lefèvre-Colau MM, Fermanian J, Revel M, Poiraudeau S. Validation of the French version of the fear avoidance belief questionnaire. Spine. 2004;29:908–13.
13. Staerkle R, Mannion AF, Elfering A, Junge A, Semmer NK, Jacobshagen N, Grob D, Dvorak J, Boos N. Longitudinal validation of the fear-avoidance beliefs questionnaire (FABQ) in a Swiss-German sample of low back pain patients. Eur Spine J. 2004;13:332–40.
14. Kovacs FM, Muriel A, Medina JM, Abraira V, Sánchez MD, Jaúregui JO. Spanish back pain research network. Psychometric characteristics of the Spanish version of the FAB questionnaire. Spine. 2006;31:104–10.
15. Georgoudis G, Papathanasiou G, Spiropoulos P, Katsoulakis K. Cognitive assessment of musculoskeletal pain with a newly validated Greek version of the fear-avoidance beliefs questionnaire (FABQ). Eur J Pain. 2007;11:341–51.
16. Korkmaz N, Akinci A, Yörükan S, Sürücü HS, Saraçbaşi O, Ozçakar L. Validation and reliability of the Turkish version of the fear avoidance beliefs questionnaire in patients with low back pain. Eur J Phys Rehabil Med. 2009;45:527–35.
17. Matsudaira K, Inuzuka K, Kikuchi N, Sakae C, Arisaka M, Isomura T. Development of the Japanese version of the fear-avoidance beliefs questionnaire (FABQ-J): translation and linguistic validation. Seikei Geka (Orthopedic surgery) 2011; 62:1301–6 (in Japanese)
18. Fujii T, Matsudaira K. Prevalence of low back pain and factors associated with chronic disabling back pain in Japan. Eur Spine J. 2013;22:432–8.
19. Dionne CE, Dunn KM, Croft PR, Nachemson AL, Buchbinder R, Walker BF, Wyatt M, Cassidy JD, Rossignol M, Leboeuf-Yde C, Hartvigsen J, Leino-Arjas P, Latza U, Reis S, Gil Del Real MT, Kovacs FM, Oberg B, Cedraschi C, Bouter LM, Koes BW, Picavet HS, van Tulder MW, Burton K, Foster NE, Macfarlane GJ, Thomas E, Underwood M, Waddell G, Shekelle P, Volinn E, Von Korff M. A consensus approach toward the standardization of back pain definitions for use in prevalence studies. Spine. 2008;33:95–103.
20. Sullivan MJL, Bishop SR, Pivik J. The pain catastrophizing scale: development and validation. Psychol Assess. 1995;7:524–32.
21. Matsuoka H, Sakano Y. Assessment of Cognitive Aspect of Pain: Development, Reliability, and Validation of Japanese Version of Pain Catastrophizing Scale. Shinshin igaku (Japanese J Psychoso Med) 2007; 47:95–102 (In Japanese)
22. Cronbach LJ. Coefficient alpha and the internal structure of tests. Psychometrika. 1951;16:297–334.
23. Cohen J. Statistical power analysis for the behavioral sciences (2nd edition). Hillsdale: Lawrence Erlbaum Associates; 1988.
24. Fukuhara S, Bito S, Green J, Hsiao A, Kurokawa K. Translation, adaptation, and validation of the SF-36 health survey for use in Japan. J Clin Epidemiol. 1998;51:1037–44.
25. Fukuhara S, Ware JE Jr, Kosinski M, Wada S, Gandek B. Psychometric and clinical tests of validity of the Japanese SF-36 Health Survey. J Clin Epidemiol. 1998;51:1045–53.
26. Yamazaki S, Fukuhara S, Green J. Usefulness of five-item and three-item Mental Health Inventories to screen for depressive symptoms in the general population of Japan. Health Qual Life Outcomes. 2005;3:48.
27. Stanton TR, Latimer J, Maher CG, Hancock M. Definitions of recurrence of an episode of low back pain: a systematic review. Spine. 2009;34:316–22.
28. Devellis RF. Scale Development Theory and Applications. Newbury Park: Sage Publications, Inc.; 1991.
29. Koes BW, van Tulder M, Lin CW, Macedo LG, McAuley J, Maher C. An updated overview of clinical guidelines for the management of non-specific low back pain in primary care. Eur Spine J. 2010;19:2075–94.
30. Bushnell DM, Martin ML, Parasuraman B. Electronic versus paper questionnaires: a further comparison in persons with asthma. J Asthma. 2003;40:751–62.
31. Gwaltney CJ, Shields AL, Shiffman S. Equivalence of electronic and paper-and-pencil administration of patient-reported outcome measures: a meta-analytic review. Value Health. 2008;11:322–33.

Japan College of Rheumatology
MODERN RHEUMATOLOGY

http://informahealthcare.com/mor
ISSN 1439-7595 (print), 1439-7609 (online)

Mod Rheumatol, 2014; 24(2): 343–348
© 2014 Japan College of Rheumatology
DOI: 10.3109/14397595.2013.854067

informa healthcare

ORIGINAL ARTICLE

Prevalence of low back pain as the primary pain site and factors associated with low health-related quality of life in a large Japanese population: a pain-associated cross-sectional epidemiological survey

Koji Yamada[1], Ko Matsudaira[2], Katsushi Takeshita[1], Hiroyuki Oka[3], Nobuhiro Hara[1], and Yasuo Takagi[4]

[1]Department of Orthopaedic Surgery, Faculty of Medicine, The University of Tokyo, Tokyo, Japan, [2]Clinical Research Center for Occupational Musculoskeletal Disorders, Kanto Rosai Hospital, Kanagawa, Japan, [3]Department of Joint Disease Research, 22nd Century Medical and Research Center, The University of Tokyo, Tokyo, Japan, and [4]Graduate School of Health Management, Keio University, Kanagawa, Japan

Abstract

Objectives. This study aimed to estimate the prevalence, magnitude, and direction of the associations among disability, pain intensity, number of pain sites, and health-related quality of life (HRQoL) in patients reporting low back pain (LBP) as their primary pain.
Methods. In January 2009, an Internet survey was performed for randomly selected adults aged 20–79 years who were registered as Internet research volunteers. Of 20 044 respondents, individuals with LBP as the primary pain were analyzed for associations among disability, number of pain sites, and HRQoL. Factors associated with low HRQoL were examined using multiple logistic regression modeling.
Results. Of the 20 044 respondents, 25.2 % ($n = 5060$) reported LBP and 13.5 % ($n = 2696$) reported LBP as their primary pain. Among those with LBP as the primary pain, HRQoL decreased with increase in disability and number of pain sites. In multivariate analyses, disability [adjusted odds ratio (aOR), 2.93–4.58], number of pain sites (aOR, 1.42–6.12), pain intensity ≥7 (aOR, 1.88), and age ≥60 years (aOR, 1.55) were associated with low HRQoL.
Conclusions. Approximately 13.5 % of patients reported LBP as their primary pain. Disability with absence from social activity and ≥7 pain sites were strongly associated with low HRQoL.

Keywords

Disability, EQ-5D, Low back pain, Multisite pain, Sick leave

History

Received 27 December 2012
Accepted 25 March 2013
Published online 10 April 2013

Introduction

Low back pain (LBP) is a common [1], costly [2], and, at times, disabling [3] condition that can lead to disability and sick leave from work or school. Pain at this site often fluctuates over time with frequent recurrences or exacerbations [4, 5]. The prevalence of LBP has been reported to range from 12–33 % [4] due to the methodologic heterogeneity across LBP prevalence studies [6, 7]. LBP is the most frequent and most expensive cause of work-related disability [8] and can affect health-related quality of life (HRQoL). LBP is a part of musculoskeletal pain [9, 10], but only one-sixth to one-third of individuals who suffer from LBP have LBP as their only pain source. Most LBP respondents also have pain at other sites [10]; this pain could be the primary reason for their disability. Moreover, a positive correlation was reported between the number of pain sites and functional problems in a large clinical study [9]. However, the prevalence and the impact of working disability and number of pain sites on HRQoL in those who have LBP as the primary pain have not been well examined.

Correspondence to: Koji Yamada, Department of Orthopaedic Surgery, Faculty of Medicine, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan. Tel: +81-3-3815-5411. Fax: +81-3-3818-4082. E-mail: forpatients2008@gmail.com

Therefore, the aim of this study was to estimate the prevalence, magnitude, and direction of the associations among disability, pain intensity, number of pain sites, and HRQoL in those reporting LBP as their primary pain in the pain-associated cross-sectional epidemiological (PACE) survey, which covers a large Japanese population.

Materials and methods

Subjects

The PACE survey was a cross-sectional Internet survey designed to evaluate the prevalence and characteristics of musculoskeletal pain in a large Japanese population. The study was performed over 10–18 January, 2009. Respondents were recruited at random from 1 477 585 research volunteers who were registered with an Internet survey company (Rakuten Research Inc., Tokyo, Japan), consistent with the Japanese demographic composition [11]. An invitation to participate in the research was sent through an e-mail containing a link to the survey. Double registration was prevented by checking the e-mail address and disabling the link to the questionnaire once the responder completed the survey. Forms were configured to automatically reject incomplete questionnaires. An additional credit point for Internet shopping was given as a financial incentive to the responders. On 18 January, 2009, the survey was closed when the number of respondents reached 20 063; thus,

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the response rate is not relevant in this survey. Individuals whose reported age was <20 years or >79 years were excluded; thus, 20 044 participants were retained. This study was approved by Keio University's institutional review board.

Measures

The questionnaire included questions regarding musculoskeletal pain in the previous month and various individual factors. The respondents were asked about the characteristics of their musculoskeletal pain, such as the pain site(s), pain intensity at each site, site of the primary pain, duration of the primary pain, and disability due to the primary pain. Pain intensity was scored with a numeric rating scale (NRS) comprising 11 points (0 = no pain, 10 = worst pain imaginable). Disability was classified into three categories using a modified graded chronic pain scale (GCPS) [12], based on disability for social activity, such as work, school, and housework. Those with LBP and no disability were classified as modified GCPS grade 1, those with LBP and disability for social activity as modified GCPS grade 2, and those with LBP and disability leading to absence from social activity as modified GCPS grade 3. Respondents were asked about their demographic characteristics, including age, sex, occupational status, and HRQoL. HRQoL was measured using the Japanese EQ-5D instrument [13].

Definition of LBP

LBP was defined as pain experienced (over the previous month) below the costal margin and above the inferior gluteal folds, as described on the full-body manikin (Fig. 1, site 13), excluding those with pain around the anus (Fig. 1, site 21). Chronic LBP was defined as pain lasting ≥3 months.

EQ-5D

The EQ-5D instrument is a standardized general system for describing and valuing HRQoL [14]. It has good reliability and validity,

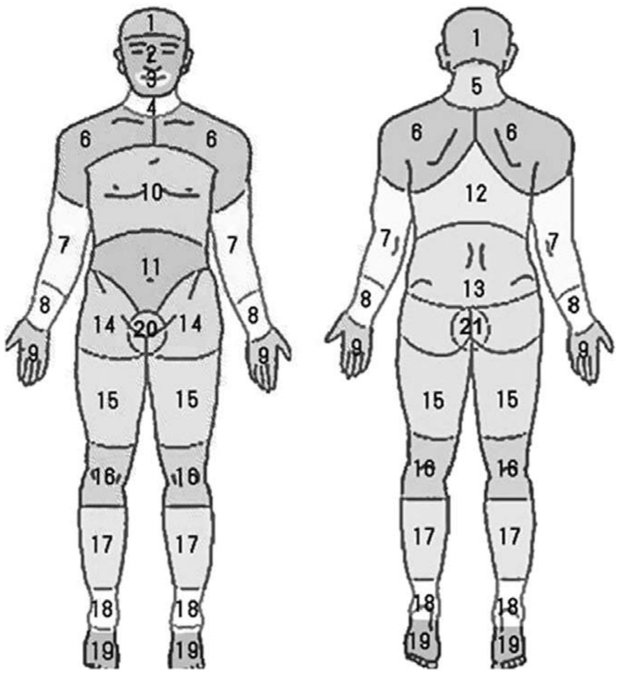

Fig. 1 The full-body manikin used in the pain-associated cross-sectional epidemiological (PACE) survey. Low back pain was defined as pain experienced below the costal margin and above the inferior gluteal folds, described as site number 13, excluding those with pain around the anus (site number 21)

and comprises five dimensions (mobility, self-care, usual activity, pain/discomfort, anxiety/depression) that are rated on three levels (1 = no problem, 2 = some problem, 3 = extreme problem); thus, it generates 243 theoretically possible health states (11111 = full health, 33333 = most extreme state).

Statistical analysis

First, the 1-month prevalence was calculated for those who had any LBP, LBP as the primary pain, and LBP as the only pain source (localized LBP). Further analyses were performed for those reporting LBP as their primary pain site using SPSS version 18 (IBM Corp., Armonk, N.Y., USA). Spearman's rho correlation coefficient was used to assess the correlations among HRQoL (EQ-5D score), disability, number of pain sites (other than LBP), and pain intensity (NRS score). For logistic regression analysis, the lowest 20 % of the EQ-5D scores in the total study population of the PACE survey was used as the dependent variable. A two-sided 5 % significance level was used in all statistical tests.

Results

LBP prevalence

Of the 20 044 respondents, 9746 (48.6 %) were men, and the overall mean score on the EQ-5D was 0.850 [standard error (SE), 0.001] with a ceiling effect of 45.7 % (9165 respondents; Table 1). The 1-month prevalence of LBP was 25.2 % (5060 respondents), of which only approximately half (2696 respondents; 13.5 % of all respondents) reported LBP as their primary pain and about one-seventh (706 respondents; 3.5 % of all respondents) reported LBP as their only pain source.

HRQoL in those with LBP as the primary pain

Further analyses were conducted for those with LBP as their primary pain. Of the 2696 respondents who reported LBP as the primary pain, 53.8 % (n = 1,424) were men, 78.1 % (n = 2,106) had chronic pain, 55.3 % (n = 1,491) reported LBP and no disability (modified GCPS grade 1), and 44.7 % (n = 1,205) reported disability for social activity with or without absence from social

Table 1. Characteristics of the total study population (n = 20,044)

Characteristic	n (%)
Age group (years)	
20–29	1,981 (9.9)
30–39	3,903 (19.5)
40–49	3,923 (19.6)
50–59	4,328 (21.6)
60–69	4,126 (20.6)
70–79	1,783 (8.9)
Mean ± SD	49.0 ± 14.2
Sex	
Male	9,746 (48.6)
Occupational status	
Worker	10,597 (52.9)
Housework and/or retired	7,655 (38.2)
Other (including student)	1,792 (8.9)
LBP prevalence	
Any LBP[a]	5,060 (25.2)
LBP as primary pain[b]	2,696 (13.5)
Localized LBP[c]	706 (3.5)
EQ5D score, mean ± SE	0.850 ± 0.001
Ceiling effect	9,165 (45.7)

LBP Low back pain, *SE* standard error
[a]Prevalence of respondents with LBP
[b]Prevalence of respondents with LBP as the primary pain site
[c]Prevalence of respondents with LBP as the only pain source

Table 2. Overall and by sex characteristics of respondents with LBP as the primary pain

Characteristic	Overall, *n* (%; *n* = 2696)	Men, *n* (%; *n* = 1424)	Women, *n* (%; *n* = 1272)
Age group (years)			
20–29	196 (7.3)	80 (5.6)	116 (9.1)
30–39	476 (17.7)	229 (16.1)	247 (19.4)
40–49	597 (22.1)	298 (20.9)	299 (23.5)
50–59	596 (22.1)	287 (20.2)	309 (24.3)
60–69	537 (19.9)	295 (20.7)	242 (19.0)
70–79	294 (10.9)	235 (16.5)	59 (4.6)
Mean ± SD	50.2 ± 13.8	52.4 ± 14.3	47.8 ± 12.9
Occupational status			
Worker	1,459 (54.1)	916 (64.3)	543 (42.7)
Housework and/or retired	1,013 (37.6)	395 (27.7)	618 (48.6)
Other (including student)	224 (8.3)	113 (7.9)	111 (8.7)
Duration of LBP			
Acute (<3 months)	526 (19.5)	281 (19.7)	245 (19.3)
Chronic (>3 months)	2,106 (78.1)	1,123 (78.9)	983 (77.3)
Unknown/refused to answer	64 (2.4)	20 (1.4)	44 (3.5)
Disability			
Grade 1[a]	1,491 (55.3)	808 (56.7)	683 (53.7)
Grade 2[b]	876 (32.5)	445 (31.3)	431 (33.9)
Grade 3[c]	329 (12.2)	171 (12.0)	158 (12.4)
NRS score (mean ± SE)	5.0 ± 0.0	4.8 ± 0.1	5.2 ± 0.1
Number of pain sites other than LBP (mean ± SE)	1.8 ± 0.0	1.6 ± 0.0	2.1 ± 0.1
EQ5D score (mean ± SE)	0.776 ± 0.003[d]	0.779 ± 0.004	0.772 ± 0.004

LBP Low back pain, *NRS* numeric rating scale, *SE* standard error
[a]LBP without disability for social activity, such as work, school, and housework
[b]LBP with disability for social activity, such as work, school, and housework
[c]LBP with disability leading to absence from social activity, such as work, school, and housework
[d]EQ5D score was significantly lower than that of the total study population (unpaired *t* test, $P < 0.01$)

activity (Table 2). The mean EQ-5D score was 0.776 (SE, 0.003), which was significantly lower than that of the total study population (unpaired *t* test, $P < 0.01$).

Next, the associations among HRQoL, number of pain sites, and pain intensity according to disability were analyzed (Table 3). We found that HRQoL decreased (Spearman's rank correlation coefficient, −0.371; $P < 0.01$) while pain intensity increased (Spearman's rank correlation coefficient, 0.418; $P < 0.01$) with higher disability. An increase in the number of pain sites was seen only between grade 1 and grade 2 disabilities (Table 3). Based on further evaluation of HRQoL stratified by age, sex, and disability, mean EQ-5D scores generally were lower in those with higher age and higher disability, and in women (Table 4).

Further analyses were conducted to evaluate the association among each variable stratified by the number of pain sites (Table 5). The number of respondents with LBP as a part of multisite pain was approximately 6.2 times larger than the number of those with localized LBP. In this analysis, HRQoL showed a negative correlation with the number of pain sites (Spearman's rank correlation coefficient, −0.256; $P < 0.01$). HRQoL was highest when the pain was localized, and lowest when the number of pain sites was ≥ 7. The proportion of those with disability for social activity (modified GCPS grades 2 and 3) and pain intensity also showed a positive correlation with the number of pain sites (Spearman's rank correlation coefficient, 0.184 and 0.359, respectively; both $P < 0.01$).

Factors associated with low HRQoL

In multivariate analyses adjusted by modified GCPS, number of pain sites, sex, age, and pain intensity, all the variables except sex were positively associated with low HRQoL (Table 6). The odds were higher as both disability and number of pain sites increased. Disability with absence from social activity and number of pain sites ≥ 7 had a strong relationship with low HRQoL. Similar trends were observed in both men and women; however, the impacts of absence from social activity and number of pain sites ≥ 7 were stronger in women than in men.

Discussion

In the present study, the 1-month prevalence of LBP was 25.2 % (5060 respondents), which is similar to that reported by Suzukamo and colleagues [15], who noted 30.6 % as the 1-month prevalence in Japan. Interestingly, of the 5060 respondents, only approximately half (2696 respondents; 13.5 % of all respondents) reported LBP as their primary pain, with the majority reporting chronicity. Recently, LBP has been recognized as a part of widespread musculoskeletal pain. Natvig and colleagues [10] reported that only

Table 3. Mean number of pain sites other than LBP, EQ5D score, and NRS score based on the disability of respondents with LBP as their primary pain

Disability (modified GCPS)	*n*	EQ5D score[d] (mean ± SE)	No. of pain sites other than LBP (mean ± SE)	NRS score[e] (mean ± SE)
Grade 1[a]	1,491	0.817 ± 0.003	1.5 ± 0.0	4.2 ± 0.0
Grade 2[b]	876	0.736 ± 0.004	2.3 ± 0.1	5.8 ± 0.1
Grade 3[c]	329	0.694 ± 0.009	2.3 ± 0.1	6.5 ± 0.1

GCPS Graded chronic pain scale, *LBP* low back pain, *NRS* numeric rating scale, *SE* standard error
[a]LBP without disability for social activity, such as work, school, and housework
[b]LBP with disability for social activity, such as work, school, and housework
[c]LBP with disability leading to absence from social activity, such as work, school, and housework
[d]EQ5D score showed a negative correlation with higher disability (Spearman's rank correlation coefficient, –0.371; $P < 0.01$)
[e]NRS score showed a positive correlation with higher disability (Spearman's rank correlation coefficient, 0.418; $P < 0.01$)

Table 4. Mean EQ5D score based on age, sex, and disability of respondents with LBP as the primary pain

Disability		Total (Grades 1 + 2 + 3)			Grade 1[a]			Grade 2[b]			Grade 3[c]		
Sex	Age (years)	*n*	Mean	SE	*n*	Mean	q	*n*	Mean	SE	*n*	Mean	SE
All	20–29	196	0.797	0.009	110	0.822	0.011	69	0.774	0.015	17	0.732	0.043
	30–39	476	0.785	0.006	236	0.828	0.008	173	0.756	0.009	67	0.706	0.021
	40–49	597	0.789	0.005	311	0.830	0.007	213	0.757	0.009	73	0.712	0.017
	50–59	596	0.777	0.006	360	0.817	0.006	172	0.727	0.010	64	0.686	0.021
	60–69	537	0.770	0.006	320	0.814	0.007	155	0.714	0.010	62	0.683	0.021
	70–79	294	0.729	0.008	154	0.782	0.009	94	0.676	0.010	46	0.659	0.026
	Total	2,696	0.776	0.003	1,491	0.817	0.003	876	0.736	0.004	329	0.694	0.009
Male	20–29	80	0.812	0.015	51	0.822	0.017	24	0.781	0.031	5	0.850	0.062
	30–39	229	0.794	0.009	114	0.837	0.011	80	0.772	0.013	35	0.702	0.033
	40–49	298	0.796	0.008	159	0.828	0.009	109	0.757	0.013	30	0.764	0.027
	50–59	287	0.781	0.008	172	0.820	0.009	81	0.725	0.014	34	0.718	0.024
	60–69	295	0.778	0.008	180	0.817	0.009	80	0.722	0.013	35	0.701	0.022
	70–79	235	0.734	0.008	132	0.781	0.009	71	0.666	0.011	32	0.689	0.034
	Total	1,424	0.779	0.004	808	0.817	0.004	445	0.734	0.006	171	0.718	0.013
Female	20–29	116	0.787	0.012	59	0.822	0.015	45	0.770	0.017	12	0.682	0.050
	30–39	247	0.777	0.008	122	0.820	0.011	93	0.743	0.012	32	0.710	0.024
	40–49	299	0.783	0.008	152	0.832	0.010	104	0.756	0.011	43	0.676	0.021
	50–59	309	0.773	0.008	188	0.814	0.008	91	0.730	0.014	30	0.650	0.034
	60–69	242	0.760	0.010	140	0.809	0.011	75	0.706	0.015	27	0.659	0.040
	70–79	59	0.708	0.020	22	0.787	0.034	23	0.704	0.020	14	0.590	0.035
	Total	1272	0.772	0.004	683	0.818	0.005	431	0.738	0.006	158	0.668	0.013

LBP Low back pain, *SE* standard error

[a]LBP without disability for social activity, such as work, school, and housework

[b]LBP with disability for social activity, such as work, school, and housework

[c]LBP with disability leading to absence from social activity, such as work, school, and housework

25 % of 893 participants who reported LBP during the previous week had localized LBP. In our study, the number of those with LBP as a part of multisite pain was about 6.2 times larger than the number of those with localized LBP. Previous studies [9, 10] have reported that many LBP respondents have pain elsewhere, which could be the primary reason for their disability. Therefore, we focused on LBP respondents reporting LBP as their primary pain for further analyses in this study.

In the present study, the mean EQ-5D score of those with LBP as their primary pain was 0.776 (SE, 0.003), which was significantly lower than that of the total study population [0.850 (SE, 0.001); $P < 0.01$], and slightly lower than the average score of patients with stage 5 chronic kidney disease (CKD) in Japan (0.798; 95 % CI, 0.757–0.839) [16]. Since stage 5 CKD represents established kidney failure, the similar HRQoL obtained in the present study indicates that the HRQoL of those who suffer from LBP could be as low as, or even lower than, those who are candidates for hemodialysis.

Generally, lower HRQoL is reported with higher disability in LBP patients [8, 17, 18]. Kovacs and colleagues revealed a negative correlation between the Rolland Morris Disability Questionnaire and the EQ-5D in LBP [8, 18]. In the present study, we used the GCPS [12], a well validated scale for assessing LBP disability, with minor revision. The revision was made to focus on disability and absence from social activity because the impacts of these disabilities on HRQoL have not been well examined. In our study, there was a negative correlation between disability and HRQoL, as in previous studies [8, 17, 18]. The differences in the mean EQ-5D scores between those with and those without disability and absence were 0.08 and 0.04, respectively. Interestingly, the differences were similar to the minimal clinically important difference reported in previous studies (0.033–0.074) [19, 20]. Collectively, these data suggest that the presence of disability for social activity and its severity regarding absence might have a significant meaning for those who suffer from LBP. Therefore, improvement of these disabilities might represent a clinically important difference, which needs further investigation.

In our study, HRQoL decreased as the number of pain sites increased, thus showing a negative correlation, whereas the proportion of disability and pain intensity increased as the pain sites increased. Kamaleri and colleagues [9] revealed that single-site pain did not have a large impact on physical fitness, feelings, or daily and social activities, and that functional problems increased markedly, in an almost linear manner, with increase in number of pain sites. From another study, the widest variation in health-related functioning, such as the items on the short form-36, was observed by the number of pain sites, with lower function seen with increase in number of pain sites [21]. LBP patients also have lower general health, poorer function, and poorer long-term work disability when their LBP is accompanied by multisite pain [10, 22, 23]. Our findings are consistent with those of previous reports, showing a similar relationship among pain intensity, disability, HRQoL, and number of pain sites in LBP responders. The reason why the majority of those with LBP as their primary pain also reported multisite pain could be the generalized hyperalgesia known to exist in

Table 5. Proportion of LBP with disability, and mean EQ5D and NRS scores based on number of pain sites other than LBP in respondents with LBP as the primary pain

Number of pain sites other than LBP	*n*	EQ5D score[a] (mean ± SE)	LBP with working disability[b] (%)	NRS score[c] (mean ± SE)
0	706	0.813 ± 0.005	35.7	4.1 ± 0.1
1–3	1,582	0.776 ± 0.003	44.0	5.1 ± 0.1
4–6	325	0.729 ± 0.007	59.7	6.1 ± 0.1
≥7	83	0.644 ± 0.014	75.9	7.1 ± 0.2
Total	2,696	0.776 ± 0.002	44.7	5.0 ± 0.0

LBP Low back pain, *NRS* numeric rating scale, *SE* standard error

[a]EQ5D score showed a negative correlation with the number of pain sites other than LBP (Spearman's rank correlation coefficient, −0.256; $P < 0.01$)

[b]Proportion of those with working disability (modified graded chronic pain scale grade 2 or 3 disability) showed a positive correlation with the number of pain sites other than LBP (Spearman's rank correlation coefficient, 0.184; $P < 0.01$)

[c]NRS score showed a positive correlation with the number of pain sites other than LBP (Spearman's rank correlation coefficient, 0.359; $P < 0.01$)

Table 6. Logistic regression analysis (dependent variable = lowest 20 % of EQ5D scores in total study population)

	Total[a]				Male[b]				Female[b]			
		95 % CI				95 % CI				95 % CI		
Variable	Adjusted odds	Lower	Upper	*P* value	Adjusted odds	Lower	Upper	*P* value	Adjusted odds	Lower	Upper	*P* value
Modified GCPS												
Grade 1	1.000				1.000				1.000			
Grade 2	2.930	2.393	3.589	<0.001	3.151	2.377	4.177	<0.001	2.750	2.052	3.686	<0.001
Grade 3	4.580	3.488	6.013	0.001	3.789	2.603	5.517	<0.001	5.642	3.780	8.420	<0.001
No. of pain sites other than LBP												
0	1.000				1.000				1.000			
1–3	1.420	1.128	1.786	0.003	1.173	0.873	1.576	0.290	1.850	1.275	2.685	0.001
4–6	2.367	1.733	3.232	<0.001	2.146	1.365	3.375	0.001	2.856	1.816	4.492	<0.001
≧7	6.124	3.541	10.589	<0.001	4.579	2.010	10.432	<0.001	8.426	3.970	17.882	<0.001
Sex												
F/M	1.044	0.868	1.256	0.644								
Age (years)												
<60	1.000				1.000					1.000		
≧60	1.545	1.271	1.879	<0.001	1.598	1.234	2.068	<0.001	1.485	1.097	2.011	0.010
NRS score												
<7	1.000				1.000					1.000		
≧7	1.883	1.541	2.300	<0.001	2.129	1.608	2.820	<0.001	1.650	1.238	2.200	0.001

CI Confidence interval, *F* female, *GCPS* graded chronic pain scale, *LBP* low back pain, *M* male, *NRS* numeric rating scale
[a]Multivariate analysis adjusted by modified GCPS, number of pain sites other than LBP, sex, age, and NRS score
[b]Multivariate analysis adjusted by modified GCPS, number of pain sites other than LBP, age, and NRS score

LBP patients [24]. Compared with healthy control subjects, LBP patients exhibit significantly lower pressure pain thresholds at all sites [25, 26]. The continuous nociceptive input might initiate central sensitization [27], which could develop widespread pain in those with LBP as their primary pain [24, 27].

In multivariate analyses, after adjusting for all the variables, modified GCPS grade, number of pain sites, age ≥60 years, and pain intensity were found to be associated with low HRQoL. Among these variables, disability with absence from social activity and ≥7 pain sites showed a stronger association than pain intensity (NRS score ≥7) and age ≥60 years. A similar tendency was seen in both men and women, highlighting the importance of multisite pain and disability in those who suffer from LBP. Although our study had limitations (due to its cross-sectional design), we believe the strong relationships seen in our study are noteworthy. Based on our results, occupational management [28, 29] focusing on returning to work, and management of multisite pain might have a more significant effect on HRQoL improvement than the management of pain itself in those who suffer from LBP. Further study is necessary to evaluate the effects of such management.

The strengths of our study include the large size of the population sample used to estimate the prevalence of those with LBP as their primary pain, and the magnitude of the associations among disability, pain intensity, number of pain sites, and HRQoL without any missing data. Some results support the validity of the PACE survey. First, the mean EQ-5D score of the PACE survey was similar to that found in a well-designed general population study (0.835) [30]. Second, the ceiling effect of the EQ-5D seen in the total study population also was similar to that reported in previous studies (42.5–47.0 %) [30–32]. Third, the percentage of those with LBP was similar to that reported previously in Japan [15]. Fourth, the percentage of workers in the total study population (52.8 %) was similar to that announced by the Japanese Ministry of Internal Affairs and Communications in 2009 (56.9 %) [11].

Some limitations in our study are notable, however. First, the selection bias due to the nature of an Internet survey needs to be addressed [33]. Although the study was conducted nationwide, using one of the largest domestic Internet survey companies, the volunteers from whom our sample was drawn were over-representative of people living in large cities, compared with the general population. Since LBP prevalence has geographic differences, with higher rates in urban populations than rural populations [34], caution is needed when interpreting the results of this study. Second, those who participate as Internet research volunteers may differ from the general population, and even from general Internet users. These potential differences could have affected the prevalence of LBP. Third, regarding the type of questionnaire, although a previous study reported that a Web-based questionnaire had adequate reliability compared with the paper-and-pencil version, even for older rural women [35], the mode of administration could affect the nature and rate of response [36]. Fourth, because this was a cross-sectional study, inferences cannot be drawn about causality.

In an Internet-based survey conducted in the United States, more than 27 000 individuals responded with a high response rate (75.7 %). The authors used a nationally representative Web-enabled panel of households that were recruited using a combination of random-digit dialing, landline-telephone recruiting, and address-based sampling [37]. Recruited households that did not have Internet access were provided free access via WebTV. Unlike other Internet-based surveys, the Internet-enabled panel used in the study was not limited to individuals with Internet access, and the sampling methodology was designed to ensure that the demographic characteristics of the panel were similar to those of the United States population. The methods used in this United States study maintain the representativeness of the study, while utilizing the advantages of Internet-based surveys for collecting a large amount of data. Such methodologic improvement might be necessary in our future studies.

Conclusion

Only approximately half of the LBP respondents reported LBP as their primary pain; among them, HRQoL decreased with higher disability and an increase in the number of pain sites. The presence of ≥7 pain sites and disability resulting in absence from social activity were strongly associated with low HRQoL. Occupational management focusing on return to work and management of multisite pain may have a more significant effect on HRQoL improvement than the management of pain itself in individuals with LBP.

Further research should focus on the effectiveness of such management in LBP respondents.

Acknowledgments

This study was supported by the dissemination project on the 13 fields of occupational injuries and illness of the Japan Labor Health and Welfare Organization. All investigations were conducted in conformity with ethical principles of research, and informed consent was obtained for participation in the study.

Conflict of interest

None.

References

1. Jacob T. Low back pain incident episodes: a community-based study. Spine J. 2006;6:306–10.
2. Maniadakis N, Gray A. The economic burden of back pain in the UK. Pain. 2000;84:95–103.
3. Derebery VJ, Giang GM, Saracino G, Fogarty WT. Evaluation of the impact of a low back pain educational intervention on physicians' practice patterns and patients' outcomes. J Occup Environ Med. 2002;44:977–84.
4. Airaksinen O, Brox JI, Cedraschi C, Hildebrandt J, Klaber-Moffett J, Kovacs F, et al. Chapter 4. European guidelines for the management of chronic nonspecific low back pain. Eur Spine J. 2006;15(Suppl 2): S192–300.
5. van Tulder M, Koes B, Bombardier C. Low back pain. Best Pract Res Clin Rheumatol. 2002;16:761–75.
6. Dionne CE, Dunn KM, Croft PR, Nachemson AL, Buchbinder R, Walker BF, et al. A consensus approach toward the standardization of back pain definitions for use in prevalence studies. Spine (Phila Pa 1976). 2008;33:95–103.
7. Leboeuf-Yde C, Lauritsen JM. The prevalence of low back pain in the literature. A structured review of 26 Nordic studies from 1954 to 1993. Spine (Phila Pa 1976). 1995;20:2112–8.
8. Kovacs FM, Abraira V, Zamora J, Teresa Gil del Real M, Llobera J, Fernandez C, et al. Correlation between pain, disability, and quality of life in patients with common low back pain. Spine (Phila Pa 1976). 2004;29:206–10.
9. Kamaleri Y, Natvig B, Ihlebaek CM, Bruusgaard D, et al. Localized or widespread musculoskeletal pain: does it matter? Pain. 2008; 138:41–6.
10. Natvig B, Bruusgaard D, Eriksen W. Localized low back pain and low back pain as part of widespread musculoskeletal pain: two different disorders? A cross-sectional population study. J Rehabil Med. 2001;33:21–5.
11. Japanese Ministry of Internal Affairs and Communications. Statistics Bureau, Director-General for Policy Planning (Statistical Standards) and Statistical Research and Training Institute. http://www.stat.go.jp/data/jinsui/2007np/index.htm. Accessed Mar 16, 2012; (in Japanese).
12. Van Korff M, Ormel J, Keefe FJ, Dworkin SF. Grading the severity of chronic pain. Pain. 1992;50:133–49.
13. Tsuchiya A, Ikeda S, Ikegami N, Nishimura S, Sakai I, Fukuda T, et al. Estimating an EQ-5D population value set: the case of Japan. Health Econ. 2002;11:341–53.
14. EuroQol–a new facility for the measurement of health-related quality of life. The EuroQol Group. Health Policy. 1990;16:199–208.
15. Suzukamo Y, Takahashi N, Konno S, Kikuchi S, Fukuhara S. Outcome study of low back pain. Pharma Medica. 2007;25:9–12 (in Japanese).
16. Tajima R, Kondo M, Kai H, Saito C, Okada M, Takahashi H, et al. Measurement of health-related quality of life in patients with chronic kidney disease in Japan with EuroQol (EQ-5D). Clin Exp Nephrol. 2010;14:340–8.
17. Garratt AM, Klaber Moffett J, Farrin AJ. Responsiveness of generic and specific measures of health outcome in low back pain. Spine (Phila Pa 1976). 2001;26:71–7; (discussion 7).
18. Kovacs FM, Abraira V, Zamora J, Fernandez C; Spanish Back Pain Research Network. The transition from acute to subacute and chronic low back pain: a study based on determinants of quality of life and prediction of chronic disability. Spine (Phila Pa 1976). 2005;30:1786–92.
19. Burstrom K, Johannesson M, Rehnberg C. Deteriorating health status in Stockholm 1998–2002: results from repeated population surveys using the EQ-5D. Qual Life Res. 2007;16: 1547–53.
20. Walters SJ, Brazier JE. Comparison of the minimally important difference for two health state utility measures: EQ-5D and SF-6D. Qual Life Res. 2005;14:1523–32.
21. Saastamoinen P, Leino-Arjas P, Laaksonen M, Martikainen P, Lahelma E. Pain and health related functioning among employees. J Epidemiol Community Health. 2006;60:793–8.
22. Natvig B, Eriksen W, Bruusgaard D. Low back pain as a predictor of long-term work disability. Scand J Public Health. 2002;30:288–92.
23. Leveille SG, Bean J, Ngo L, McMullen W, Guralnik JM. The pathway from musculoskeletal pain to mobility difficulty in older disabled women. Pain. 2007;128:69–77.
24. Kindler LL, Bennett RM, Jones KD. Central sensitivity syndromes: mounting pathophysiologic evidence to link fibromyalgia with other common chronic pain disorders. Pain Manag Nurs. 2011;12: 15–24.
25. O'Neill S, Manniche C, Graven-Nielsen T, Arendt-Nielsen L. Generalized deep-tissue hyperalgesia in patients with chronic low-back pain. Eur J Pain. 2007;11:415–20.
26. Laursen BS, Bajaj P, Olesen AS, Delmar C, Arendt-Nielsen L. Health related quality of life and quantitative pain measurement in females with chronic non-malignant pain. Eur J Pain. 2005;9:267–75.
27. Woolf CJ. Central sensitization: implications for the diagnosis and treatment of pain. Pain. 2011;152:S2–15.
28. Loisel P, Abenhaim L, Durand P, Esdaile JM, Suissa S, Gosselin L, et al. A population-based, randomized clinical trial on back pain management. Spine (Phila Pa 1976). 1997;22:2911–8.
29. Lemstra M, Olszynski WP. The effectiveness of standard care, early intervention, and occupational management in worker's compensation claims. Spine (Phila Pa 1976). 2003;28:299–304.
30. Saarni SI, Harkanen T, Sintonen H, Suvisaari J, Koskinen S, Aromaa A, et al. The impact of 29 chronic conditions on health-related quality of life: a general population survey in Finland using 15D and EQ-5D. Qual Life Res. 2006;15:1403–14.
31. Burstrom K, Johannesson M, Diderichsen F. Swedish population health-related quality of life results using the EQ-5D. Qual Life Res. 2001;10:621–35.
32. Nordlund A, Ekberg K, Kristenson M. EQ-5D in a general population survey–a description of the most commonly reported EQ-5D health states using the SF-36. Qual Life Res. 2005;14:1099–109.
33. Eysenbach G, Wyatt J. Using the Internet for surveys and health research. J Med Internet Res. 2002;4:E13.
34. Volinn E. The epidemiology of low back pain in the rest of the world. A review of surveys in low- and middle-income countries. Spine (Phila Pa 1976). 1997;22:1747–54.
35. Boeckner LS, Pullen CH, Walker SN, Abbott GW, Block T. Use and reliability of the World Wide Web version of the Block Health Habits and History Questionnaire with older rural women. J Nutr Educ Behav. 2002;34(Suppl 1):S20–4.
36. Turner CF, Ku L, Rogers SM, Lindberg LD, Pleck JH, Sonenstein FL. Adolescent sexual behavior, drug use, and violence: increased reporting with computer survey technology. Science. 1998;280: 867–73.
37. Johannes CB, Le TK, Zhou X, Johnston JA, Dworkin RH. The prevalence of chronic pain in United States adults: results of an Internet-based survey. J Pain. 2010;11:1230–9.

Japan College of Rheumatology
MODERN RHEUMATOLOGY

http://informahealthcare.com/mor
ISSN 1439-7595 (print), 1439-7609 (online)

Mod Rheumatol, 2014; 24(2): 236–242

DOI: 10.3109/14397595.2013.854055

informa healthcare

ORIGINAL ARTICLE

Association of dietary intake with joint space narrowing and osteophytosis at the knee in Japanese men and women: the ROAD study

Shigeyuki Muraki[1], Toru Akune[1], Yoshio En-yo[2], Munehito Yoshida[2], Sakae Tanaka[3], Hiroshi Kawaguchi[3], Kozo Nakamura[4], Hiroyuki Oka[5], and Noriko Yoshimura[5]

[1]*Department of Clinical Motor System Medicine, 22nd Century Medical and Research Center, Faculty of Medicine, The University of Tokyo, Tokyo, Japan,* [2]*Department of Orthopaedic Surgery, Wakayama Medical University, Wakayama, Japan,* [3]*Department of Orthopaedic Surgery, Faculty of Medicine, The University of Tokyo, Tokyo, Japan,* [4]*Rehabilitation Services Bureau, National Rehabilitation Center for Persons with Disabilities, Saitama, Japan, and* [5]*Department of Joint Disease Research, 22nd Century Medical and Research Center, Faculty of Medicine, The University of Tokyo, Tokyo, Japan*

Abstract

Objective. The objective of the present study is to identify dietary nutrients associated with joint space narrowing (JSN) and osteophytosis at the knee in a population-based cohort of the Research on Osteoarthritis/osteoporosis Against Disability (ROAD) study.
Methods. From the baseline survey of the ROAD study, 827 participants (305 men and 522 women) in a rural cohort were analyzed. Dietary nutrient intakes for the last month were assessed by a self-administered brief diet history questionnaire. Minimum joint space width (mJSW) and osteophyte area (OPA) in the medial compartment of the knee were measured using a knee osteoarthritis (OA) computer-aided diagnostic system.
Results. In men, there were no associations of dietary nutrient intakes with mJSW or OPA. In women, vitamins K, B1, B2, B6, and C were associated with mJSW after adjustment for age, body mass index, and total energy ($p < 0.05$). Vitamins E, K, B1, B2, niacin, and B6 were significantly associated with OPA ($p < 0.05$) in women. Vitamins K, B and C may have a protective role against knee OA in women and might lead to disease-modifying treatments.
Conclusions. The present study revealed that low dietary intake of vitamins K, B, and C are associated with JSN and osteophytosis in women.

Keywords

Osteoarthritis, Knee, Diet, Cohort studies, Epidemiology

History

Received 25 October 2012
Accepted 25 February 2013
Published online 16 March 2013

Introduction

Knee osteoarthritis (OA), characterized by pathological features including joint space narrowing (JSN) and osteophytosis, is a major public health issue causing chronic pain and disability in the elderly in most developed countries [1]. The prevalence of radiographic knee OA is high in Japan [2], with 25,300,000 subjects aged 40 years and older estimated to experience radiographic knee OA [3]. According to the recent National Livelihood Survey of the Ministry of Health, Labour, and Welfare in Japan, OA is ranked fourth among diseases that cause disabilities that subsequently require support with activities of daily living [4]. Despite the urgent need for strategies for the prevention and treatment of this condition, there have been few established risk factors for knee OA except for age, female sex, obesity, previous injury, and occupational activities [5].

Current recommendations for OA include a combination of nonpharmacological interventions and pharmacological treatments [6]. However, considering that nonsteroidal anti-inflammatory drugs (NSAIDs), which may have serious adverse effects with long-term use, remain among the most widely prescribed drugs for OA [7], there is a need for safe and effective alternative strategies for prevention and treatment of this disease. Such strategies could come from dietary nutrition, because dietary factors are modifiable.

There have been several epidemiologic studies on the relationship between nutritional factors and OA [8–15]. Our previous study showed that dietary vitamin K intake was associated with the prevalence of knee OA [14], but disease was defined according to a categorical grade such as the Kellgren–Lawrence (KL) grade [16]. In the Framingham Study, the association of nutrition with JSN and osteophytosis was separately analyzed [8, 9, 12, 13] in Caucasians, but they were also defined by categorical grades. Categorical methods are statistically less powerful than continuous methods. Thus, the association between nutrition and knee OA might have been underestimated in previous studies.

To overcome these problems, joint space width or osteophyte area should be evaluated using a fully automatic system. To the best of our knowledge, there have been no population-based studies to separately measure joint space width or osteophyte area to clarify the association of dietary nutrient intake with JSN and osteophytosis. In the present study, we measured medial minimum joint space width (mJSW) and osteophyte area (OPA) at the knee in the large-scale population-based cohort study called Research on Osteoarthritis/osteoporosis Against Disability (ROAD). The

Correspondence to: Shigeyuki Muraki, Department of Clinical Motor System Medicine, 22nd Century Medical and Research Center, Faculty of Medicine, The University of Tokyo, Hongo 7-3-1, Bunkyo-ku, Tokyo 113-8655, Japan. Tel: +81-3-58009178. Fax: +81-3-58009179. E-mail: murakis-ort@h.u-tokyo.ac.jp

purpose of the present study is to clarify which nutritional factors were associated with JSN and osteophytosis.

Materials and methods

Subjects

The ROAD study is a nationwide prospective study designed to establish epidemiologic indices for evaluation of clinical evidence for the development of a disease-modifying treatment for bone and joint diseases (OA and osteoporosis are the representative bone and joint diseases, respectively). It consists of population-based cohorts in three communities in Japan. A detailed profile of the ROAD study has been described elsewhere [2, 3, 17]; a brief summary is provided here. To date, we have completed the creation of a baseline database that includes clinical and genetic information for 3,040 subjects (1,061 men and 1,979 women) ranging in age from 23 to 95 years (mean, 70.3 years), who were recruited from resident registration listings in three communities: an urban region in Itabashi, Tokyo; a mountainous region in Hidakagawa, Wakayama; and a coastal region in Taiji, Wakayama.

Residents of these regions were recruited from the resident registration list of the relevant region. Participants in the urban region were recruited from a randomly selected cohort from the Itabashi-ward residents' registration database [18]. The participation rate was 75.6 %. Participants in mountainous and coastal regions were also recruited from the resident registration lists, and the participation rates in these two areas were 56.7 and 31.7 %, respectively. The inclusion criteria, apart from residence in the communities mentioned above, were the ability to (1) walk to the survey site, (2) report data, and (3) understand and sign an informed consent form. The baseline survey of the ROAD study was completed in 2006. All participants provided written informed consent, and the study was conducted with the approval of the ethics committees of the University of Tokyo and the Tokyo Metropolitan Institute of Gerontology.

From the baseline data of 855 subjects aged ≥40 years in the mountainous cohort, we excluded 3 individuals who had undergone knee surgeries. In addition we excluded 18 individuals who had lateral knee OA, defined as being present when a knee had KL grade ≥2 and lateral JSN score ≥1 on a 0–3 scale according to the Osteoarthritis Research Society International (OARSI) atlas [19]. We also excluded 4 who did not complete questionnaires regarding dietary nutrition, and 3 whose radiographic conditions were insufficient for measuring JSN and osteophyte area. Thus, a total of 827 participants (305 men and 522 women) were analyzed in the present study.

Dietary assessment

For the dietary survey, we used a self-administered brief diet history questionnaire (BDHQ) and investigated dietary nutrient intakes for the previous month. A questionnaire was given to each participant with detailed explanation to fill out at home, and was reviewed by well-trained interviewers when the participants visited the clinic. The BDHQ is a 4-page, structured questionnaire that inquires about the consumption frequency of 56 food and beverage items, with specified serving sizes described in terms of a natural portion or the standard weight and volume measurement of servings commonly consumed in general Japanese populations. The BDHQ was developed based on a comprehensive (16-page) version of a validated self-administered diet history questionnaire [20], and is now widely used for dietary survey in Japan [14, 21]. Estimates of dietary intake for the 56 food and beverage items, energy, and selected nutrients were calculated using an ad hoc computer algorithm for the BDHQ, which was based on the Standard Tables of Food Composition in Japan. In the present study, dietary intake levels of total energy and 15 nutrient factors (animal protein, vegetable protein, animal fat, vegetable fat, carbohydrate, vitamin B1, 2, 6, and 12, niacin, vitamins C, D, E, K, and salt) were analyzed.

Radiographic assessment

All participants had radiographic examination of both knees using an anterior–posterior view with weight-bearing and foot map positioning. The beam was positioned parallel to the floor with no angle and aimed at the joint space. To visualize the joint space properly and to make the patella centralized over the lower end of the femur, we used fluoroscopic guidance with an anterior–posterior X-ray beam. The images were downloaded into digital imaging and communication in medicine (DICOM) format files. mJSW (mm) in the medial compartment and OPA (mm^2) at the medial tibia were measured by the KOACAD system, and the knee with lower mJSW was defined as the designated knee of each participant. The KOACAD system has been described in detail elsewhere [22–24], and is summarized here only briefly. The KOACAD system can quantify the major features of knee OA on standard radiographs and allows objective, accurate, simple, and easy assessment of the structural severity of knee OA in general clinical practice. This system was programmed to measure mJSW in the medial and lateral compartments and OPA at the medial tibia using digitized knee radiographs. Initially, correction for radiographic magnification was performed based on the image size of a rectangular metal plate. Next, to determine the region of interest (ROI), the center of the tibiofemoral joint was determined as follows: A vertical neighborhood difference filter that vertically scanned digital images to detect the margins of the tibial and femoral condyles was applied to identify points with high absolute values for differences of scale. Then, the center of all points was calculated and defined as the center of the tibiofemoral joint. Finally, a 480 × 200 pixel rectangle around the center was defined as the ROI. Within the ROI, the outline of the femoral condyle was designated as the upper rim of the joint space by vertical filtering with a 3 × 3 square neighborhood difference filter. Both ends of the upper rim were determined using a Canny filter to remove the noise associated with lines, and vertical lines from the ends were designated as the outside rims of the joint space. Outlines of anterior and posterior margins of the tibial plateau were drawn similarly to that of the femoral condyle, and the middle line between the two outlines was designated as the lower rim of the joint space (Fig. 1a). A straight regression line for the lower rim outline was then drawn, and the intersection of the lower rim outline and the regression line was designated as the inside rim. Medial and lateral joint space areas were determined as areas surrounded by the upper, lower, inside, and outside rims as defined above. Medial and lateral mJSWs were further determined as the minimum vertical distances in the respective joint space area (Fig. 1b). To measure the OPA, medial and lateral outlines of the femur and tibia were drawn. Inflection points for these outlines were then calculated. The medial outline of the tibia from the inflection point was drawn upward to the joint level, and the area that was medially prominent over the smoothly extended outline was designated as the OPA (Fig. 1c). We examined the reproducibility of mJSW and OPA measured on radiographs taken at 2-week intervals for 20 individuals; the reproducibility of both mJSW and OPA were high [intraclass correlation coefficient (ICC) = 0.86 and 0.99, respectively] [22]. In addition, we measured mJSW and OPA by KOACAD more than twice on 1979 radiographs, and confirmed that all parameters were unchanged independent of observer or time measured (all ICC = 1.0) [22]. We have previously published reference values of joint space width and osteophyte area by gender and age strata in Japan using the KOACAD system [25].

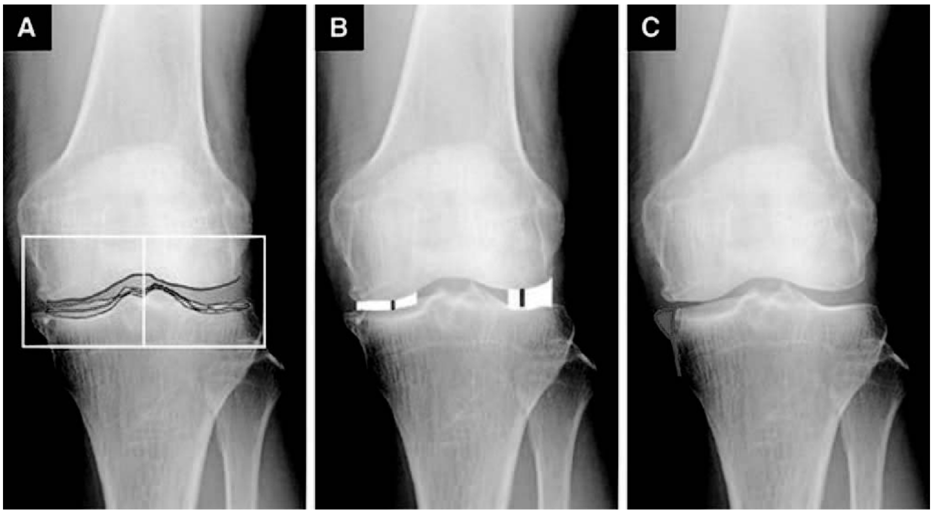

Fig 1. Schema of image processing by KOACAD (cited from Ref. [28]). (a) Outlines of anterior and posterior margins of the tibial plateau. The *middle line* between the two outlines is defined as the lower rim of the joint space. (b) Medial and lateral minimum joint space widths were defined as the minimum vertical distances in the joint space area. (c) Osteophyte area (*red area*) that is medially prominent over the smoothly extended outline of the tibia

Statistical analysis

Differences in age, height, weight, and body mass index (BMI) were examined by nonpaired Student's *t* test. mJSW, OPA, total energy, and dietary nutrient intakes between men and women were examined by Wilcoxon rank-sum test. The distribution of mJSW, OPA, total energy, and dietary nutrient intakes were not normal, thus we applied log transformation to these variables, and multiple regression analysis after adjustment for age, BMI, gender, and total energy was used to determine the association of dietary nutrient intakes with mJSW and OPA in the overall population. Furthermore, multiple regression analysis after adjustment for age, BMI, and total energy was used to determine the association of dietary nutrient intakes with mJSW and OPA in men and women. Data analyses were performed using SAS version 9.0 (SAS Institute Inc., Cary, NC). *p*-Value <0.05 was considered significant.

Results

Characteristics of 827 participants are presented in Table 1. There were no significant differences in BMI between men and women. mJSW was significantly wider in men than women, and OPA was significantly smaller in men than women. Total energy and almost all of dietary nutrient intakes except for vitamins K and C were significantly higher in men than women ($p < 0.01$), whereas vitamin C intake was significantly lower in men than women ($p < 0.0001$) (Table 2). Vitamin K intake was not significantly different between men and women ($p = 0.07$).

Table 1. Characteristics of participants

	Overall	Men	Women	*p* Value
No. of participants	827	305	522	
Age (years)	69.2 ± 9.3	69.6 ± 8.7	68.9 ± 9.6	0.29
Height (cm)	163.0 ± 9.2	161.3 ± 6.7	148.1 ± 6.6	<0.0001
Weight (kg)	54.0 ± 10.2	60.0 ± 10.2	50.5 ± 8.5	<0.0001
BMI (kg/m^2)	23.0 ± 3.2	23.0 ± 3.0	23.0 ± 3.4	0.86
mJSW (mm)	2.43 ± 1.11	2.91 ± 1.01	2.15 ± 1.07	<0.0001
OPA (mm^2)	3.72 ± 8.33	1.72 ± 4.20	4.88 ± 9.79	<0.0001

Data are mean ± standard deviation (SD). Nonpaired Student's *t* test was used to compare age, height, and BMI between men and women. Wilcoxon rank-sum test was used to compare mJSW and OPA between men and women

BMI body mass index, *mJSW* minimum joint space width, *OPA* osteophyte area

We next analyzed the association of dietary nutrient intakes with mJSW and OPA. Overall, after adjustment for age, BMI, gender, and total energy, mJSW was not associated with vitamins D, E, B1 or niacin, but was significantly associated with vitamins K ($R = 0.344$, $p = 0.03$), B2 ($R = 0.343$, $p = 0.04$), and C ($R = 0.345$, $p = 0.02$) (Table 3). OPA was not significantly associated with vitamins D, E, K, B12, C or niacin, but was significantly associated with vitamins B1 ($R = 0.421$, $p = 0.03$), B2 ($R = 0.421$, $p = 0.03$), and B6 ($R = 0.422$, $p = 0.02$) (Table 3). When analyzed in men and women separately, in men, multiple regression analysis after adjustment for age, BMI, and total energy showed that mJSW and OPA were not significantly associated with any nutritional factors (Table 4). In contrast, in women, mJSW was significantly associated with vitamins K ($R = 0.283$, $p = 0.01$), B1 ($R = 0.271$, $p = 0.04$), B2 ($R = 0.270$, $p = 0.04$), B6 ($R = 0.273$, $p = 0.01$), and C ($R = 0.281$, $p = 0.01$) (Table 5), while OPA was significantly associated with vitamins E ($R = 0.426$, $p = 0.04$), K ($R = 0.427$, $p = 0.03$), B1 ($R = 0.436$,

Table 2. Dietary nutrient intakes in men and women

	Overall	Men	Women
Total energy, MJ/day	7.6 (6.3–9.3)	9.5 (8.1–12.1)	6.9* (6.0–7.9)
Dietary nutrients			
Vitamin D, μg/day	17.7 (11.5–25.8)	20.7 (13.3–30.5)	16.4* (10.7–24.2)
Vitamin E, mgα-TE/day	6.9 (5.4–8.8)	7.4 (5.6–9.6)	6.7* (5.3–8.3)
Vitamin K, μg/day	211.0 (146.6–287.9)	224.4 (150.2–313.5)	202.9 (145.3–281.0)
Vitamin B1, mg/day	0.71 (0.58–0.86)	0.79 (0.64–0.97)	0.67* (0.56–0.80)
Vitamin B2, mg/day	0.97 (0.76–1.19)	1.07 (0.82–1.34)	0.92* (0.73–1.12)
Niacin, mgNE/day	14.9 (11.6–19.2)	17.9 (13.9–22.7)	13.6* (10.4–17.1)
Vitamin B6, mg/day	1.1 (0.9–1.4)	1.3 (1.0–1.6)	1.03* (0.86–1.26)
Vitamin B12, μg/day	9.8 (6.8–13.5)	11.0 (7.7–15.8)	8.8* (6.3–12.0)
Vitamin C, mg/day	101.7 (78.3–133.4)	94.0 (71.7–122.0)	108.1* (82.6–137.3)

Values are median (interquartile range)

TE tocopherol equivalent, *NE* niacin equivalent

*$p < 0.01$ versus men by Wilcoxon rank-sum test

Table 3. Association of dietary nutrient intakes with mJSW and OPA overall

	mJSW (mm)			OPA (mm^2)		
	Regression coefficient	95 % CI	*p*-Value	Regression coefficient	95 % CI	*p* Value
Vitamin D, μg/day	0.006	−0.04 to 0.06	0.8044	−0.03	−0.09 to 0.02	0.2000
Vitamin E, mgα-TE/day	0.01	−0.08 to 0.10	0.7613	−0.08	−0.17 to 0.02	0.1114
Vitamin K, μg/day	0.06	0.006 to 0.11*	0.0309	−0.05	−0.11 to 0.004	0.0665
Vitamin B1, mg/day	0.09	−0.05 to 0.23	0.2058	−0.17	−0.32 to 0.02*	0.0271
Vitamin B2, mg/day	0.10	0.004 to 0.20*	0.0418	−0.12	−0.22 to 0.01*	0.0254
Niacin, mgNE/day	0.02	−0.08 to 0.13	0.6422	−0.09	−0.20 to 0.01	0.0877
Vitamin B6, mg/day	0.12	−0.001 to 0.24	0.0526	−0.15	−0.28 to 0.03*	0.0164
Vitamin B12, μg/day	0.04	−0.02 to 0.09	0.2066	−0.03	−0.09 to 0.02	0.2515
Vitamin C, mg/day	0.09	0.01 to 0.16*	0.0179	−0.04	−0.12 to 0.03	0.2640

Log transformation was applied to variables, and multiple regression analysis after adjustment for age, body mass index, gender, and total energy was used to determine the association of nutritional factors with mJSW and OPA

mJSW minimum joint space width, *OPA* osteophyte area, *TE* tocopherol equivalent, *NE* niacin equivalent, *CI* confidence interval

$p = 0.002$), B2 ($R = 0.435$, $p = 0.003$), niacin ($R = 0.428$, $p = 0.02$), and B6 ($R = 0.433$, $p = 0.01$) (Table 5).

Discussion

This is the first population-based cohort study of the relationship between dietary nutrient intakes and JSN and osteophytosis separately in Japanese men and women. In the overall population, vitamins K, B2, and C were significantly associated with mJSW, while vitamins B1, B2, and B6 were significantly associated with OPA. When analyzed in men and women separately, we observed that there were no associations of dietary nutrient intakes with mJSW or OPA in men. In contrast, in women, vitamins K, B1, B2, and B6 were associated with both mJSW and OPA. Vitamin C was associated with mJSW, but not with OPA. Previous studies have already shown that vitamins K and C were associated with knee OA; however, the knee OA was defined by KL grade or other categorical methods in almost all studies [8–15]. KL grade is the most conventional system to grade radiographic severity of knee OA, but in this categorical system, JSN and osteophyte formation are not assessed separately, thus one cannot clarify whether osteophytosis and JSN have distinct risk factors. In addition, a recent cross-sectional study showed that osteophytosis was unrelated to JSN on plain radiographs [26]. Furthermore, our study on an experimental mouse model for OA identified a cartilage-specific molecule, carminerin, that regulates osteophytosis without affecting joint cartilage destruction during OA progression [27, 28]. In addition, there were distinct effects on quality of life (QOL) for JSN and osteophytosis [26]. Such accumulating evidence indicates that JSN and osteophytosis may have distinct etiologic mechanisms and their progression may be neither constant nor proportional. Thus, to examine factors associated with knee OA, these two OA features should be separately assessed. Furthermore, because categorical methods are statistically less powerful than continuous methods, the association between nutrition and knee OA might have been underestimated in previous studies. This study is the first to report that vitamins K, B1, B2, and B6 are significantly associated with both mJSW and OPA, and that vitamin C is significantly associated with mJSW in women. The association of dietary factors with knee OA may be weaker than for gender or obesity, but they are easily modifiable; therefore, these results may contribute to prevent incidence or progression of knee OA, although it is not completely clear what modifications of vitamin intake would be required to achieve clinically meaningful change in mJSW and OPA.

Vitamin K includes vitamin K1, or phylloquinone, which is contained in green leafy vegetables, and vitamin K2, or menaquinone, which is synthesized by bacteria and abundantly contained in a traditional Japanese fermented soybean food called *natto* [29]. Our previous study showed that dietary vitamin K intake was inversely associated with prevalence of knee OA defined by KL grade [14]. However, because of the different etiology that

Table 4. Association of dietary nutrient intakes with mJSW and OPA in men

	mJSW (mm)			OPA (mm^2)		
	Regression coefficient	95 % CI	*p* Value	Regression coefficient	95 % CI	*p* Value
Vitamin D, μg/day	−0.02	−0.10 to 0.06	0.5804	0.04	−0.03 to 0.11	0.2710
Vitamin E, mgα-TE/day	−0.01	−0.14 to 0.11	0.8501	0.03	−0.09 to 0.14	0.6567
Vitamin K, μg/day	0.02	−0.06 to 0.09	0.6626	−0.01	−0.08 to 0.06	0.7939
Vitamin B1, mg/day	−0.01	−0.21 to 0.19	0.8995	0.08	−0.11 to 0.26	0.4275
Vitamin B2, mg/day	0.07	−0.08 to 0.22	0.3515	0.05	−0.09 to 0.19	0.4772
Niacin, mgNE/day	−0.03	−0.18 to 0.12	0.7149	0.06	−0.08 to 0.20	0.4127
Vitamin B6, mg/day	0.04	−0.13 to 0.22	0.6214	−0.005	−0.17 to 0.16	0.9554
Vitamin B12, μg/day	−0.004	−0.09 to 0.09	0.9345	0.06	−0.03 to 0.14	0.1816
Vitamin C, mg/day	0.03	−0.03 to 0.14	0.5079	0.01	−0.08 to 0.11	0.8113

Log transformation was applied to variables, and multiple regression analysis after adjustment for age, body mass index, and total energy was used to determine the association of nutritional factors with mJSW and OPA

mJSW minimum joint space width, *OPA* osteophyte area, *TE* tocopherol equivalent, *NE* niacin equivalent, *CI* confidence interval

Table 5. Association of dietary nutrient intakes with mJSW and OPA in women

	mJSW (mm)			OPA (mm^2)		
	Regression coefficient	95 % CI	*p* Value	Regression coefficient	95 % CI	*p* Value
Vitamin D, μg/day	0.03	−0.03 to 0.09	0.3550	−0.07	−0.14 to 0.004	0.0631
Vitamin E, mgα-TE/day	0.05	−0.08 to 0.18	0.4234	−0.15	−0.29 to −0.008*	0.0383
Vitamin K, μg/day	0.11	0.03 to 0.19*	0.0062	−0.10	−0.18 to −0.009*	0.0302
Vitamin B1, mg/day	0.21	0.01 to 0.41*	0.0366	−0.35	−0.56 to −0.13*	0.0020
Vitamin B2, mg/day	0.13	0.006 to 0.26*	0.0411	−0.22	−0.37 to −0.08*	0.0025
Niacin, mgNE/day	0.08	−0.06 to 0.21	0.2819	−0.18	−0.33 to −0.03*	0.0195
Vitamin B6, mg/day	0.18	0.02 to 0.34*	0.0261	−0.25	−0.42 to −0.07*	0.0053
Vitamin B12, μg/day	0.07	−0.005 to 0.14	0.0679	−0.07	−0.16 to 0.006	0.0699
Vitamin C, mg/day	0.13	0.04 to 0.23*	0.0077	−0.09	−0.20 to 0.02	0.1139

Log transformation was applied to variables, and multiple regression analysis after adjustment for age, body mass index, and total energy was used to determine the association of nutritional factors with mJSW and OPA

mJSW minimum joint space width, *OPA* osteophyte area, *TE* tocopherol equivalent, *NE* niacin equivalent, *CI* confidence interval

may exist between JSN and osteophytosis, these two OA features should be assessed separately to examine factors associated with knee OA. However, the association of these two features with vitamin K cannot be separately analyzed by KL grade. The Framingham Study showed that plasma levels of phylloquinone were inversely associated with osteophytosis in the knee [12], but no population-based study has determined the association of dietary vitamin K intake with mJSW width and OPA separately. In the present study, vitamin K was associated with both JSN and osteophytosis in women, although the results for vitamin K were of borderline significance after adjusting for additional potential confounders, particularly regarding OPA. Several basic studies have shown that vitamin K plays an important role in cartilage metabolism, as an inhibitor of extracellular matrix calcification as well as a promoter of cell survival and proliferation [30–38]. In addition, warfarin, a vitamin K-antagonist anticoagulant, is known to cause warfarin embryopathy characterized by abnormal calcification and decreased growth of cartilage [37, 38]. Habitual low dietary vitamin K intake may exert an inhibitory effect on the vitamin K-dependent MGP and Gas6 functions and modulate the pathogenesis of OA by influencing the process of osteophytosis and cartilage destruction.

Several previous studies have shown that vitamin C intake was inversely associated with knee OA [9, 15], but no population-based study has analyzed the association of vitamin C intake with mJSW and OPA at the same time. In the present study, vitamin C was associated with narrower mJSW in women, but not with OPA. This finding may indicate that vitamin C intake is more strongly associated with JSN than with osteophytosis in women. Damage caused by free radicals has long been thought to be pathogenic, and free radicals play an important role in the progression of many chronic diseases, including OA [9, 11, 39–42]. Vitamin C is an antioxidant, which may partly explain the effect of vitamin C on JSN. This may lead to the logical possibility of using vitamin C supplementation for primary prevention or as a therapeutic intervention for OA.

There have been no studies regarding the association of dietary vitamin B intake with knee OA. In the present study, we found that vitamins B1, B2, and B6 were significantly associated with mJSW in women. Vitamin B is closely involved in the metabolism of homocysteine [43], which has recently been seen to play a role in osteoporosis-related bone damage, and may be linked to its involvement in collagen formation. Homocysteine inhibits the synthesis of insoluble collagen fibrils in vitro by interfering with normal cross-linking [44]. From the perspective of cartilage homeostasis, these changes in matrix organization interfere with chondrocyte-mediated mineralization, potentially altering the function and properties of calcified cartilage [45]. This may be due to homocysteine-mediated inhibition of lysil oxidase, which catalyzes the cross-linking of collagen molecules, a function necessary for its mineralization in bone tissue [46].

In the present study, we found gender differences regarding the association of dietary nutrient intakes with mJSW and OPA. In women, vitamins B and K were significantly associated with both mJSW and OPA, and vitamin C was significantly associated with mJSW, whereas in men, no dietary factors were significantly associated with mJSW or OPA. This difference may be partly explained by muscle strength in men. Because men are known to have greater muscle strength than women at all ages, and muscle strength has a protective effect on knee OA [47–49], it might be that the greater muscle strength obscures the effects of dietary nutrient intakes on knees in men.

There are several limitations to the present study. First, this was a cross-sectional study of baseline data, and thus no causal relationship can be determined. Second, in the present study, we used self-reported measures for dietary assessments; these measurements are prone to bias and measurement error. In addition, the dietary survey in this study investigated dietary habits only for the previous month, which did not necessarily reflect a long habit of several years, despite the fact that OA is a slowly progressing chronic disease. This dietary survey also investigated whether participants had changed their dietary habits. Those who answered "yes" accounted for 9.6 %, whereas 90.4 % of participants answered that they had not changed their dietary habits. Although it is likely that dietary habits in middle-aged and elderly people are usually quite different from those in children and young adults, there is a possibility that most participants in this study had not changed their dietary habits for several years or for a longer time, which may have affected the disease process of OA. Furthermore, the dietary survey in the present study was conducted from autumn to winter although there are four seasons in Japan and diets may vary with the season. Therefore, the present study could suffer from some bias for the effect of season on the nutritional quality of diets. Third, nutritional factors cannot be assumed to be joint location specific, and osteophytes may even be more pronounced in the contralateral tibiofemoral compartment [50]; however, at present, the KOACAD system can only measure medial osteophytes at the tibia. We are now developing a KOACAD system to measure osteophytes at other sites; thus, we may be able to clarify the association between osteophytes at other sites and QOL in the near future. Finally, we clarified the association of vitamins B, C, and K with mJSW and OPA, but did not determine what changes in intake of these vitamins would be needed to achieve clinically meaningful change in mJSW and OPA, because we have not yet clarified what changes in mJSW and OPA are clinically meaningful. In addition, this is a cross-sectional study, thus causal relationships of vitamins B, C, and K with mJSW and OPA cannot be clarified.

In conclusion, the present cross-sectional study using a population-based cohort revealed that low dietary intakes of vitamins K, B1, B2, and B6 are associated with both JSN and osteophytosis in women. Vitamin C intake was associated with JSN in women, but not with osteophytosis. Further studies, along with longitudinal data from the ROAD study, will elucidate the environmental background of OA and help clarify clinical evidence regarding the development of disease-modifying treatments.

Acknowledgments

The present study was supported by a Grant-in-Aid for Scientific Research (B20390182, C20591737, C20591774), for Young Scientists (A18689031), and for Exploratory Research (19659305) from the Japanese Ministry of Education, Culture, Sports, Science, and Technology, H17-Men-eki-009, H18-Choujyu-037, and H20-Choujyu-009 from the Ministry of Health, Labour, and Welfare, and Research Aid from the Japanese Orthopaedic Association (JOA-Subsidized Science Project Research 2006-1); and Grant No. 166 from the Japan Orthopaedics and Traumatology Foundation. The authors thank Mrs. Tomoko Takijiri and other members of the Public Office in Hidakagawa Town; and Mrs. Tamako Tsutsumi, Mrs. Kanami Maeda, and other members of the Public Office in Taiji Town, for their assistance in the location and scheduling of participants for examinations.

Conflict of interest

None.

References

1. Sharma L, Kapoor D. Epidemiology of osteoarthritis. In: Moskowitz RW, Altman RD, Hochberg MC, Buckwalter JA, Goldberg VM. Osteoarthritis: diagnosis and medical/surgical management. 4th ed. Philadelphia: Lippincott Williams & Wilkins; 2007. p. 3–26.
2. Muraki S, Oka H, Akune T, Mabuchi A, En-yo Y, Yoshida M, et al. Prevalence of radiographic knee osteoarthritis and its association with knee pain in the elderly of Japanese population-based cohorts: the ROAD study. Osteoarthr Cartil. 2009;17:1137–43.
3. Yoshimura N, Muraki S, Oka H, Mabuchi A, En-yo Y, Yoshida M, et al. Prevalence of knee osteoarthritis, lumbar spondylosis and osteoporosis in Japanese men and women: the Research on Osteoarthritis/osteoporosis Against Disability (ROAD). J Bone Miner Metab. 2009;27:620–8.
4. Ministry of Health, Labour and Welfare. The outline of the results of National Livelihood Survey 2007. http://www.mhlw.go.jp/toukei/list/20-19-1.html. Accessed 1 Oct 2012.
5. Blagojevic M, Jinks C, Jeffery A, Jordan KP. Risk factors for onset of osteoarthritis of the knee in older adults: a systematic review and meta-analysis. Osteoarthr Cartil. 2010;18:24–33.
6. Zhang W, Moskowitz RW, Nuki G, Abramson S, Altman RD, Arden N, et al. OARSI recommendations for the management of hip and knee osteoarthritis, part I: critical appraisal of existing treatment guidelines and systematic review of current research evidence. Osteoarthr Cartil. 2007;15:981–1000.
7. Simon LS, Strand V. The pharmacologic treatment of osteoarthritis. In: Moskowitz RW, Altman RD, Hochberg MC, Buckwalter JA, Goldberg VM. Osteoarthritis: diagnosis and medical/surgical management. 4th ed. Philadelphia: Lippincott Williams & Wilkins; 2007. p. 267–86.
8. McAlindon TE, Felson DT, Zhang Y, Hannan MT, Aliabadi P, Weissman B, et al. Relation of dietary intake and serum levels of vitamin D to progression of osteoarthritis of the knee among participants in the Framingham Study. Ann Intern Med. 1996;125:353–9.
9. McAlindon TE, Jacques P, Zhang Y, Hannan MT, Aliabadi P, Weissman B, et al. Do antioxidant micronutrients protect against the development and progression of knee osteoarthritis?. Arthritis Rheum. 1996;39:648–56.
10. McAlindon TE, Biggee BA. Nutritional factors and osteoarthritis: recent developments. Curr Opin Rheumatol. 2005;17:647–52.
11. Ameye LG, Chee WS. Osteoarthritis and nutrition. From nutraceuticals to functional foods: a systematic review of the scientific evidence. Arthritis Res Ther. 2006;8:R127.
12. Neogi T, Booth SL, Zhang YQ, Jacques PF, Terkeltaub R, Aliabadi P, et al. Low vitamin K status is associated with osteoarthritis in the hand and knee. Arthritis Rheum. 2006;54:1255–61.
13. Felson DT, Niu J, Clancy M, Aliabadi P, Sack B, Guermazi A, et al. Low levels of vitamin D and worsening of knee osteoarthritis: results of two longitudinal studies. Arthritis Rheum. 2007;56:129–36.
14. Oka H, Akune T, Muraki S, En-yo Y, Yoshida M, Saika A, et al. Low dietary vitamin K intake is associated with radiographic knee osteoarthritis in the Japanese elderly: dietary survey in a population-based cohort of the ROAD study. J Orthop Sci. 2009;14:687–92.
15. Peregoy J, Wilder FV. The effects of vitamin C supplementation on incident and progressive knee osteoarthritis: a longitudinal study. Pub Health Nutr. 2010;14:709–15.
16. Kellgren JH, Lawrence JS. The epidemiology of chronic rheumatism: atlas of standard radiographs of arthritis. Oxford: Blackwell Scientific; 1963.
17. Yoshimura N, Muraki S, Oka H, Kawaguchi H, Nakamura K, Akune T. Cohort profile: Research on Osteoarthritis/osteoporosis Against Disability (ROAD) Study. Int J Epidemiol. 2010;39:988–95.
18. Shimada H, Lord SR, Yoshida H, Kim H, Suzuki T. Predictors of cessation of regular leisure-time physical activity in community-dwelling elderly people. Gerontology. 2007;53:293–7.
19. Altman RD, Gold GE. Atlas of individual radiographic features in osteoarthritis, revised. Osteoarthr Cartil. 2007;15 Suppl A:A1–56.
20. Sasaki S, Yanagibori R, Amano K. Self-administered diet history questionnaire developed for health education: a relative validation of the test-version by comparison with 3-day diet record in women. J Epidemiol. 1998;8:203–15.
21. Murakami K, Mizoue T, Sasaki S, Ohta M, Sato M, Matsushita Y, et al. Dietary intake of folate, other B vitamins, and omega-3 polyunsaturated fatty acids in relation to depressive symptoms in Japanese adults. Nutrition. 2008;24:140–7.
22. Oka H, Muraki S, Akune T, Mabuchi A, Suzuki T, Yoshida H, et al. Fully automatic quantification of knee osteoarthritis severity on plain radiographs. Osteoarthr Cartil. 2008;16:1300–6.
23. Muraki S, Oka H, Akune T, En-yo Y, Yoshida M, Nakamura K, et al. Association of occupational activity with joint space narrowing and osteophytosis in the medial compartment of the knee: the ROAD study. Osteoarthr Cartil. 2011;19:840–6.
24. Muraki S, Oka H, Akune T, En-yo Y, Yoshida M, Suzuki T, et al. Independent association of joint space narrowing and osteophyte formation at the knee with health-related quality of life in Japan: a cross-sectional study. Arthritis Rheum. 2011;63:3859–64.
25. Oka H, Muraki S, Akune T, Nakamura K, Kawaguchi H, Yoshimura N. Normal and threshold values of joint space width, joint space area, osteophyte area and fibro-tibial angle using a computer-assisted measuring system (KOACAD) to evaluate knee osteoarthritis: the ROAD study. J Orthop Sci. 2010;15:781–9.
26. Muraki S, Oka H, Akune T, En-yo Y, Yoshida M, Suzuki T, et al. Independent association of joint space narrowing and osteophyte formation at the knee with health-related quality of life in Japan: a cross-sectional study. Arthritis Rheum. 2011;63:3859–64.
27. Yamada T, Kawano H, Koshizuka Y, Fukuda T, Yoshimura K, Kamekura S, et al. Carminerin contributes to chondrocyte calcification during endochondral ossification. Nat Med. 2006;12:665–70.
28. Kamekura S, Kawasaki Y, Hoshi K, Shimoaka T, Chikuda H, Maruyama Z, et al. Contribution of runt-related transcription factor 2 to the pathogenesis of osteoarthritis in mice after induction of knee joint instability. Arthritis Rheum. 2006;54:2462–70.
29. Kaneki M, Hodges SJ, Hosoi T, Fujiwara S, Lyons A, Crean SJ, et al. Japanese fermented soybean food as the major determinant of the large geographic difference in circulating levels of vitamin K2: possible implications for hip-fracture risk. Nutrition. 2001;17:315–21.
30. Furie B, Bouchard BA, Furie BC. Vitamin K-dependent biosynthesis of gamma-carboxyglutamic acid. Blood. 1999;93:1798–808.
31. Schneider C, King RM, Philipson L. Genes specifically expressed at growth arrest of mammalian cells. Cell. 1988;54:787–93.
32. Loeser RF, Varnum BC, Carlson CS, Goldring MB, Liu ET, Sadiev S, et al. Human chondrocyte expression of growth-arrest-specific gene 6 and the tyrosine kinase receptor axl: potential role in autocrine signaling in cartilage. Arthritis Rheum. 1997;40:1455–65.
33. Hafizi S, Dahlbäck B. Gas6 and protein S. Vitamin K-dependent ligands for the Axl receptor tyrosine kinase subfamily. FEBS J. 2006;273:5231–44.

34. Luo G, D'Souza R, Hogue D, Karsenty G. The matrix Gla protein gene is a marker of the chondrogenesis cell lineage during mouse development. J Bone Miner Res. 1995;10:325–34.
35. Munroe PB, Olgunturk RO, Fryns JP, Van Maldergem L, Ziereisen F, Yuksel B, et al. Mutations in the gene encoding the human matrix Gla protein cause Keutel syndrome. Nat Genet. 1999;21:142–4.
36. Luo G, Ducy P, McKee MD, Pinero GJ, Loyer E, Behringer RR, et al. Spontaneous calcification of arteries and cartilage in mice lacking matrix GLA protein. Nature. 1997;386:78–81.
37. Pauli RM, Lian JB, Mosher DF, Suttie JW. Association of congenital deficiency of multiple vitamin K-dependent coagulation factors and the phenotype of the warfarin embryopathy: clues to the mechanism of teratogenicity of coumarin derivatives. Am J Hum Genet. 1987;41:566–83.
38. Howe AM, Lipson AH, de Silva M, Ouvrier R, Webster WS. Severe cervical dysplasia and nasal cartilage calcification following prenatal warfarin exposure. Am J Med Genet. 1997;71:391–6.
39. Felson D, Zhang Y. An update on the epidemiology of knee and hip osteoarthritis with a view to prevention. Arthritis Rheum. 1998;41:1343–55.
40. Canter PH, Wider B, Ernst E. The antioxidant vitamins A, C, E and selenium in the treatment of arthritis: a systematic review of randomized clinical trials. Rheumatology. 2007;46:1223–33.
41. Kurz B, Jost B, Schünke M. Dietary vitamins and selenium diminish the development of mechanically induced osteoarthritis and increase the expression of antioxidative enzymes in the knee joint of STR/1N mice. Osteoarthr Cartil. 2002;10:119–26.
42. Sowers M, Lachance L. Vitamins and arthritis—the roles of vitamins A, C, D, and E. Rheum Dis Clin North Am. 1999;25:315–32.
43. Selhub J, Jacques PF, Wilson PW, Rush D, Rosenberg IH. Vitamin status and intake as primary determinants of homocysteinemia in an elderly population. JAMA. 1993;270:2693–8.
44. Kang AH, Trelstad RL. A collagen defect in homocystinuria. J Clin Invest. 1973;52:2571–8.
45. Khan M, Yamauchi M, Srisawasdi S, Stiner D, Doty S, Paschalis EP, et al. Homocysteine decreases chondrocyte-mediated matrix mineralization in differentiating chick limb-bud mesenchymal cell micro-mass cultures. Bone. 2001;28:387–98.
46. Lubec B, Fang-Kircher S, Lubec T, Blom HJ, Boers GH. Evidence for McKusick's hypothesis of deficient collagen cross-linking in patients with homocystinuria. Biochim Biophys Acta. 1996;1315: 159–62.
47. Sinaki M, Nwaogwugwu NC, Phillips BE, Mokri MP. Effect of gender, age, and anthropometry on axial and appendicular muscle strength. Am J Phys Med Rehabil. 2001;80:330–8.
48. McAlindon TE, Cooper C, Kirwan JR, Dieppe PA. Determinants of disability in osteoarthritis of the knee. Ann Rheum Dis. 1993;52: 258–62.
49. O'Reilly SC, Jones A, Muir KR, Doherty M. Quadriceps weakness in knee osteoarthritis: the effect on pain and disability. Ann Rheum Dis. 1998;57:588–94.
50. Felson DT, Gale DR, Elon Gale M, Niu J, Hunter DJ, Goggins J, et al. Osteophytes and progression of knee osteoarthritis. Rheumatology (Oxford). 2005;44:100–4.

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http://informahealthcare.com/mor
ISSN 1439-7595 (print), 1439-7609 (online)

Mod Rheumatol, 2014; 24(6): 966–973

DOI: 10.3109/14397595.2014.883055

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ORIGINAL ARTICLE

Association of knee osteoarthritis with onset and resolution of pain and physical functional disability: The ROAD study

Shigeyuki Muraki[1], Toru Akune[1], Keiji Nagata[2], Yuyu Ishimoto[2], Munehito Yoshida[2], Fumiaki Tokimura[3], Sakae Tanaka[4], Hiroyuki Oka[5], Hiroshi Kawaguchi[4], Kozo Nakamura[6], and Noriko Yoshimura[5]

[1]Department of Clinical Motor System Medicine, 22nd Century Medical & Research Center, Faculty of Medicine, the University of Tokyo, Tokyo, Japan, [2]Department of Orthopaedic Surgery, Wakayama Medical University, Wakayama, Japan, [3]Department of Orthopaedic Surgery, Tokyo Metropolitan Geriatric Medical Center, Tokyo, Japan, [4]Department of Orthopaedic Surgery, Faculty of Medicine, the University of Tokyo, Tokyo, Japan, [5]Department of Joint Disease Research, 22nd Century Medical & Research Center, Faculty of Medicine, the University of Tokyo, Tokyo, Japan, and [6]National Rehabilitation Center for Persons with Disabilities, Saitama, Japan

Abstract

Objectives. To examine the onset and resolution of pain and physical functional disability using Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and their association with knee osteoarthritis (OA) in the longitudinal large-scale population of the nationwide cohort study, Research on Osteoarthritis/osteoporosis Against Disability (ROAD).

Methods. Subjects from the ROAD study who had been recruited during 2005–2007 were followed up 3 years later. A total of 1,578 subjects completed the WOMAC questionnaire at baseline and follow up, and the onset and resolution rate of pain and physical functional disability were examined. We also examined the association of onset of pain and physical functional disability and their resolution with severity of knee OA as well as age, body–mass index and grip strength.

Results. After a 3.3-year follow-up, the onset rate of pain was 35.0% and 35.3% in men and women, respectively, and the onset rate of physical functional disability was 38% and 40%, respectively. Resolution rate of pain was 20.3% and 26.2% in men and women, respectively, and resolution rate of physical functional disability was 16% and 14% in men and women, respectively. Knee OA was significantly associated with onset and resolution of pain and physical functional disability in women, but there was no significant association of knee OA with onset of pain and resolution of physical functional disability in men.

Conclusions. The present longitudinal study revealed the onset rate of pain and physical functional disability as well as their resolution, and their association with knee OA.

Keywords

Knee joint, Osteoarthritis, Epidemiology, Longitudinal studies

History

Received 9 September 2013
Accepted 10 January 2014
Published online 24 February 2014

Introduction

Knee osteoarthritis (OA), characterized by pathological features including joint space narrowing and osteophytosis, is a major public health issue causing chronic pain and disability among the elderly in most developed countries [1]. The prevalence of radiographic knee OA in Japan is high [2], with 25,300,000 subjects aged 40 years and older estimated to experience radiographic knee OA [3]. According to the recent National Livelihood Survey of the Ministry of Health, Labour and Welfare in Japan, OA is ranked fourth among diseases that cause disabilities that subsequently require support with activities of daily living [4].

The principal clinical symptoms of knee OA are pain and physical functional disability [5], but the correlation of these symptoms with radiographic severity of knee OA is controversial [2,6–8]. Thus it would be interesting to determine whether the impact of radiographic knee OA on pain and physical functional disability differs according to the severity of OA. In terms of disease-specific scales for estimating pain and physical functional disability due to knee OA, the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) has been used for Caucasians [9] and Asians [10,11], although these reports were not population-based studies. Furthermore, there is little information on the impact of knee OA on onset of pain and physical functional disability using WOMAC in Japan, although a population survey suggests that the disease pattern differs among races [12–14]. In addition, to the best of our knowledge, although pain and physical functional disability can disappear or improve, there is no information on the impact of knee OA on the resolution of pain and physical functional disability.

Grip strength is a useful marker of muscle function and sarcopenia [15]. There is growing evidence that reduced grip strength is associated with adverse outcomes including morbidity, disability, falls, higher fracture rates, increased length of hospital stay and mortality [16–18]. A previous study also showed that grip strength is related to total muscle strength [19]. Thus, the association of knee OA with pain and physical functional disability may be influenced by grip strength, but again, no studies have examined the association of knee OA and grip strength with onset of pain and disability as well as their resolution simultaneously in the same population using a longitudinal cohort study.

Correspondence to: Shigeyuki Muraki, MD, PhD, Department of Clinical Motor System Medicine, 22nd Century Medical & Research Center, Faculty of Medicine, the University of Tokyo, Tokyo, Japan. Tel: + 81-3-5800-9178. Fax: + 81-3-5800-9179. E-mail: murakis-ort@h.u-tokyo.ac.jp

The objective of the present study was to clarify the onset and resolution rate of pain and physical functional disability using WOMAC in Japanese men and women who were part of the large-scale, longitudinal, population-based cohort study known as the Research on Osteoarthritis/osteoporosis Against Disability (ROAD) study. In addition, we examined the association of body-–mass index (BMI), grip strength and severity of knee OA with onset of pain and physical functional disability as well as their resolution in men and women.

Materials and methods

Subjects

The ROAD study was a nationwide prospective study for bone and joint diseases (with OA and osteoporosis as the representative bone and joint diseases) constituting population-based cohorts established in several communities in Japan. As a detailed profile of the ROAD study has already been described elsewhere [2,3,20], only a brief summary is provided here. During 2005–2007, we created a baseline database that included clinical and genetic information for 3,040 inhabitants (1,061 men; 1,979 women) aged 23–95 years (mean, 70.6 years), recruited from listings of resident registrations in three communities: an urban region in Itabashi, Tokyo; a mountainous region in Hidakagawa, Wakayama; and a coastal region in Taiji, Wakayama. All participants provided written informed consent, and the study was conducted with the approval of the ethics committees of the University of Tokyo and the Tokyo Metropolitan Institute of Gerontology. Participants completed an interviewer-administered questionnaire of 400 items that included lifestyle information such as smoking habit, alcohol consumption, family history, medical history and previous knee injury history. Furthermore, subjects were interviewed by well-experienced orthopedists regarding the treatment for knee OA, such as medication, injections, physical therapy, bracing, etc. between the baseline and follow-up study. Anthropometric measurements included height and weight, from which BMI (weight [kg]/height^2 [m^2]) was calculated. Grip strength was measured on bilateral sides using a TOEI LIGHT handgrip dynamometer (Toei Light Co., Ltd., Saitama, Japan), and the better measurement was used to represent maximum muscle strength. During 2008–2010, we attempted to trace and review all 3,040 subjects; they were invited to attend a follow-up interview. The interviews were conducted by the same trained orthopedists who undertook the baseline study during 2005–2007.

Radiographic assessment

All participants underwent radiographic examination of both knees using an anterior–posterior view with weight-bearing and foot map positioning. Fluoroscopic guidance with a horizontal anterior–posterior X-ray beam was used to properly visualize the joint space. Knee radiographs at baseline and follow-up were read in pairs without knowledge of the participant's clinical status by a single well-experienced orthopedist (S.M.), and the Kellgren Lawrence (KL) grade was defined using the KL radiographic atlas for overall knee radiographic grades [21]. In the KL grading system, radiographs are scored from grade 0 to grade 4, with the higher grades being associated with more severe OA. To evaluate the intraobserver variability of the KL grading, 100 randomly selected radiographs of the knee were scored by the same observer more than 1 month after the first reading. One hundred other radiographs were also scored by two experienced orthopedic surgeons (S.M. & H.O.) using the same atlas for interobserver variability. The intra- and inter variabilities evaluated for KL grades (0–4) were confirmed by kappa analysis to be sufficient for assessment (0.86 and 0.80, respectively).

Instruments

The WOMAC, a 24-item OA-specific index, consists of three domains: pain, stiffness and physical function. Each of these 24 items is graded on either a 5-point Likert scale or a 100-mm visual analog scale [22,9]. In the present study, we used the Likert scale (version LK 3.0). The domain score ranges from 0 to 20 for pain, 0 to 8 for stiffness and 0 to 68 for physical function. Japanese versions of the WOMAC have also been validated [23]. In the present study, onset of pain and physical functional disability were defined as WOMAC pain score $= 0$ at baseline and > 0 at follow up and WOMAC physical function score $= 0$ at baseline and > 0 at follow up, respectively. Resolution of pain and physical functional disability were defined as WOMAC pain score > 0 at baseline and $= 0$ at follow up and WOMAC physical function score > 0 at baseline and $= 0$ at follow up, respectively. Worsening pain and physical functional disability were defined as WOMAC pain and physical function at follow up was worse than at baseline, respectively.

Statistical analysis

The differences in age, height, weight, BMI, grip strength, and WOMAC pain and physical function scores at baseline and follow up between men and women were examined using a non-paired Student's t-test. The prevalence of knee OA was compared between men and women using chi-square test. Tukey's honestly significant difference test after adjustment for age and BMI was used to compare WOMAC pain and physical functional score and differences between baseline and follow up among subjects with KL $= 0/1$, 2 and 3/4. The non-paired Student's t test was used to compare age, BMI and grip strength between subjects with and without onset of pain and physical functional disability as well as those with and without resolution of pain and physical functional disability. Chi-square test was used to compare prevalence of knee OA between subjects with and without onset of pain and physical functional disability as well as those with and without resolution of pain and physical functional disability. Multiple logistic regression analysis after adjustment for age was also used to determine the association of severity of knee OA with onset of pain and physical functional disability as well as their resolution. In addition, to determine independent association of age, BMI, grip strength and knee OA with onset of pain and physical function as well as their resolution, multiple logistic regression analysis was used with significant variables ($p < 0.01$) in univariate analyses as explanatory variables. Data analyses were performed using SAS version 9.0 (SAS Institute Inc., Cary, NC).

Results

Of the 3,040 subjects in the baseline study during 2005–2007, 125 had died by the time of the review held 3 years later, 123 did not participate in the follow-up study due to bad health, 69 had moved away, 83 declined the invitation to attend the follow-up study, and 155 did not participate in the follow-up study for other reasons. Among the 2,485 subjects who did participate in the follow-up study, we excluded 39 subjects who were younger than 40 years at baseline. Those participating in the follow-up study were younger than those who did not survive or who did not participate for other reasons (responders 68.6 years, non-responders 75.1 years; $p < 0.0001$). The follow-up study participants also were more likely to be women (responders 66.3% women, nonresponders 61.8% women; $P = 0.03$) and were more likely to have knee OA at the baseline examination than either those who did not survive to follow-up or those who did not participate for other reasons (responders 51.5%, nonresponders 60.9%; $P < 0.0001$). Among them, 1,578 subjects provided completed WOMAC questionnaires both at baseline and follow up. We also excluded three subjects

Table 1. Characteristics of subjects.

	Overall	Men	Women	p value
N	1558	553	1005	
Age	67.0 ± 11.0	68.1 ± 10.7	66.5 ± 11.0	0.004
Height	155.2 ± 8.9	163.4 ± 6.5	150.8 ± 6.5	< 0.0001
Weight	55.5 ± 10.4	62.2 ± 10.2	51.8 ± 8.5	< 0.0001
BMI	22.9 ± 3.3	23.2 ± 3.1	22.8 ± 3.3	0.0043
Grip strength	27.2 ± 9.5	35.4 ± 8.7	22.7 ± 6.4	< 0.0001
Knee OA (%)	49.3	38.7	55.2	< 0.0001
WOMAC at baseline				
Pain	1.12 ± 2.18	1.02 ± 2.05	1.18 ± 2.25	0.157
Physical function	3.03 ± 6.63	2.56 ± 5.71	3.29 ± 7.07	0.0268
WOMAC at follow up				
Pain	1.82 ± 2.83	1.72 ± 2.67	1.88 ± 2.91	0.291
Physical function	5.59 ± 9.7	4.73 ± 8.30	6.06 ± 10.36	0.0061

Knee OA was defined as Kellgren Lawrence grade 2 or worse at baseline.
BMI, body–mass index; OA, osteoarthritis; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

who did not undergo plain radiography at knee and 17 subjects who underwent total knee arthroplasty before the follow-up study, leaving a total of 1,558 subjects (553 men and 1,005 women). The mean duration between baseline and follow up was 3.3 ± 0.6 years.

The characteristics of the 1,578 participants at baseline in the present study are shown in Table 1. Men were significantly older than women, and BMI was significantly higher in men than in women. The prevalence of knee OA was significantly higher in women than in men at baseline. WOMAC pain score was not significantly different between gender, while, physical function score was significantly worse in women than in men at baseline and follow up. The scores of WOMAC pain and physical function scores worsened at follow up compared with those at baseline in men and women ($p < 0.05$).

The scores of WOMAC pain and physical function scores and their differences between baseline and follow up according to the KL grade are shown in Supplementary Table 1 available online at http://informahealthcare.com/doi/abs/10.3109/14397595.2014.883055. In men, differences in WOMAC physical function scores were significantly larger in subjects with KL 3/4 than those with KL 0/1 after adjustment for age and BMI, while differences in WOMAC pain scores were not. In women, after adjustment for age and BMI, differences in WOMAC pain and physical function scores between baseline and follow up were significantly larger in subjects with KL 3/4 than those with KL 0/1.

Among 366 men and 634 women in subjects without pain at baseline, 128 (35.0%) men and 224 (35.3%) women had onset of pain at follow up (Table 2). In men, subjects with onset of pain tended to be older than those without pain, while BMI and grip strength were not significantly different between them. In women, age and BMI were significantly different between subjects with and without onset of pain, and grip strength tended to be higher in subjects with onset of pain than those without pain. Among 346 men and 601 subjects without physical functional disability at baseline, 132 (38.2%) men and 243 (40.4%) women had onset of physical functional disability at follow up (Table 2). Age and BMI were significantly different between subjects with and without onset of physical functional disability in both men and women, and BMI tended to be higher in subjects with onset of physical functional disability than those without it in women only.

We next examined onset of pain and physical functional disability according to KL grade (Figure 1). There were no significant differences in onset of pain among men with KL 0/1 knee, KL 2 knee OA and KL 3/4 knee OA (33.3%, 36.0% and 46.2%, respectively, $p = 0.4149$ by chi-square test), while there were significant differences in onset of pain among women with KL 0/1 knee, KL 2 knee OA and KL 3/4 knee OA (30.4%, 38.6% and 48.5%, respectively, $p = 0.0082$ by chi-square test). Multiple logistic regression analysis after adjustment for age showed that women with KL 3/4 knee OA had significant higher onset of pain compared with those with KL 0/1. There were significant differences in onset of physical functional disability among subjects with KL 0/1 knee OA, KL 2 knee OA and KL 3/4 knee OA in men and women (men 33.2%, 41.7% and 66.7%, respectively, $p = 0.0023$ by chi-square test, women 35.8%, 43.8% and 53.1%, respectively, $p = 0.0165$ by chi-square test). Multiple logistic regression analysis after adjustment for age showed that men with KL 3/4 knee OA had a significant higher onset of physical functional disability compared with those with KL 0/1.

In addition, we examined the association of age, BMI, grip strength and WOMAC pain and physical function scores at baseline with resolution of pain and physical functional disability (Table 3). Among 187 men and 371 women with WOMAC pain at baseline, pain disappeared in 38 (20.3%) men and 97 (26.2%) women at follow up. In men, WOMAC pain score at baseline was significantly different between subjects with resolution of pain and those with continuous pain. BMI tended to be higher in subjects with continuous pain than in those with resolution of pain. In women, age, BMI, grip strength and WOMAC pain score at baseline were significantly different between subjects with resolution of pain and those with continuous pain. Among 207 men and 404 women with physical functional disability at baseline,

Table 2. Age, BMI, grip strength, and WOMAC pain and physical function score according to onset of pain and physical functional disability in subjects without pain and physical functional disability at baseline.

	Pain $N = 1{,}000$			Physical function $N = 947$		
	Continuous no pain	Onset of pain	p value	Continuous no physical functional disability	Onset of physical functional disability	p value
Men						
N	238	128		214	132	
Age	65.3 ± 11.3	67.6 ± 10.8	0.056	63.3 ± 11.0	68.9 ± 10.2	< 0.0001
BMI	23.1 ± 3.1	23.1 ± 2.8	0.7981	23.1 ± 3.0	23.0 ± 3.2	0.8946
Grip strength	37.1 ± 8.8	36.6 ± 9.3	0.6531	37.4 ± 8.6	35.9 ± 9.1	0.0149
Women						
N	410	224		358	243	
Age	62.7 ± 11.0	65.4 ± 9.9	0.0017	60.2 ± 10.4	65.7 ± 10.0	< 0.0001
BMI	22.0 ± 3.1	22.7 ± 3.1	0.0023	22.2 ± 3.1	22.6 ± 3.1	0.0823
Grip strength	24.2 ± 6.4	23.3 ± 6.5	0.0948	25.3 ± 6.5	22.8 ± 5.3	< 0.0001

Values are the means ± standard deviation.
BMI, body mass index; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

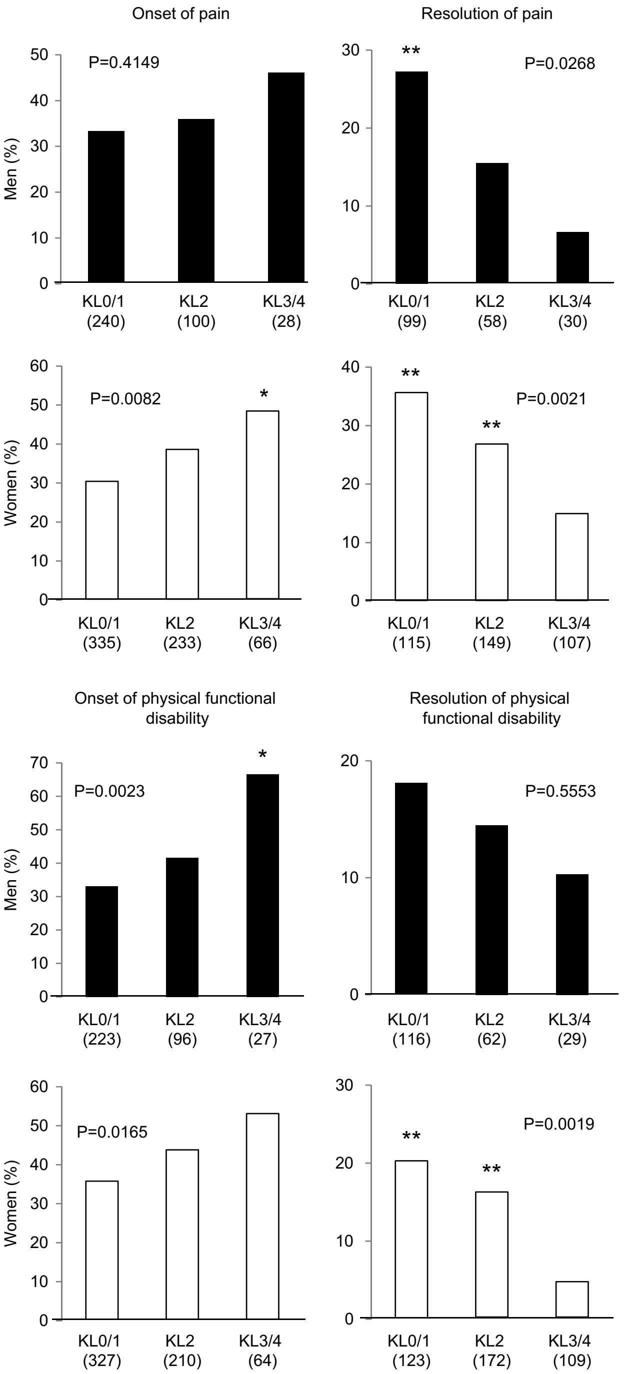

Figure 1. Onset and resolution rate of pain and physical functional disability according to Kellgren Lawrence (KL) grade in men and women. The number of subjects in each subgroup is shown in brackets. Chi-square test was used to determine the association of KL grade with onset of pain and physical functional disability as well as their resolution. *$p<0.05$ versus KL grade 0/1 by multiple logistic regression analysis after adjustment for age. **$p<0.05$ versus KL grade 3/4 by multiple logistic regression analysis after adjustment for age.

disability disappeared in 33 (15.9%) men and 58 (14.4%) women at follow up. In men, age and grip strength were significantly different between subjects with resolution of physical functional disability and those with continuous physical functional disability. Age, BMI, grip strength and WOMAC physical function score at baseline were significantly different between subjects with resolution of physical functional disability and those with continuous physical functional disability. In women, age, BMI, grip strength and WOMAC physical function score at baseline were significantly different between subjects with resolution of physical functional disability and those with continuous physical functional disability.

We next examined resolution of pain and physical functional disability according to KL grade (Figure 1). There were significant differences in resolution of pain among subjects with KL 0/1 knee, KL 2 knee OA and KL 3/4 knee OA in men and women (men 27.3%, 15.5% and 6.7%, respectively, $p=0.0268$ by chi-square test; women 35.7%, 26.8% and 15.0%, respectively, $p=0.0021$ by chi-square test). Multiple logistic regression analysis after adjustment for age showed that men with KL 3/4 knee OA had a significantly higher onset of pain compared with those with KL 0/1. Regarding resolution of physical functional disability, there were no significant differences among subjects with KL 0/1 knee, KL 2 knee OA and KL 3/4 knee OA in men (18.1%, 14.5% and 10.3%, respectively, $p=0.5553$ by chi-square test), while there were significant differences subjects with KL 0/1 knee, KL 2 knee OA and KL 3/4 knee OA in women (20.3%, 16.3% and 4.6%, respectively, $p=0.0019$ by chi-square test). Multiple logistic regression analysis after adjustment for age showed that women with KL 2 and 3/4 knee OA had a significantly higher onset of physical functional disability compared with those with KL 0/1.

To determine the independent association of age, BMI, grip strength and KL grade with onset of pain and physical functional disability, we next used multiple logistic regression analysis with significant variables ($p<0.01$) by non-paired Student's t test or chi-square test shown in Table 2 and Figure 1 as explanatory variables (Table 4). Regarding onset of pain, there were no significant variables in men; thus, we did not examine the independent association with onset of pain. In women, older age and higher BMI were independently associated with onset of pain. Older age and KL 3/4 knee OA were independent risk factors for onset of physical functional disability in men, whereas older age, higher BMI and weaker grip strength were independent risk factors for onset of physical functional disability in women. The significant association of knee OA with onset of physical functional disability disappeared after adjustment age, BMI and grip strength in women.

We also examined independent associations of age, BMI, grip strength and KL grade with resolution of pain and physical functional disability (Table 5). KL 0/1 knee and lower WOMAC pain score at baseline were significantly associated with resolution of pain in men, whereas lower BMI, higher grip strength and lower WOMAC pain score were significantly associated with resolution of pain in women. Regarding physical function, only age was significantly associated with resolution of physical functional disability in men, whereas higher grip strength, KL 2 knee OA and lower WOMAC physical function score were significantly associated with resolution of physical functional disability in women. KL 01 knee also tended to be associated with resolution of physical functional disability in women. Because treatment for knee OA might affect the resolution of pain and physical functional disability, we further examined the association of treatment for knee OA with the resolution of pain and physical functional disability. Among subjects with pain at baseline, the resolution rate of pain was 36.2% in subjects who underwent treatment for knee OA, and 14.2% in subjects who did not undergo treatment for knee OA. Among subjects with physical functional disability at baseline, the resolution rate of physical functional disability was 19.3% in subjects who underwent treatment for knee OA, while, 7.2% in subjects who did not undergo treatment for knee OA. The resolution rate of pain and physical functional disability was significantly different between subjects who had and had not undergone treatment for knee OA (chi-square test, $p<0.0001$). Thus, we examined independent associations of age, BMI, grip strength and KL grade with resolution of pain and physical functional disability after adjustment for the treatment for

Table 3. Age, BMI, grip strength, and WOMAC pain and physical function score according to resolution of pain and physical functional disability in subjects with pain and physical functional disability at baseline, respectively.

	Pain $N = 558$			Physical function $N = 611$		
	Resolution of pain	Continuous pain	p value	Resolution of physical functional disability	Continuous physical functional disability	p value
Men						
N	38	149		33	174	
Age	72.3 ± 8.9	71.9 ± 8.5	0.8	67.9 ± 11.6	73.4 ± 7.6	0.0118
BMI	22.8 ± 3.0	23.7 ± 3.3	0.08	23.4 ± 3.2	23.6 ± 3.2	0.8041
Grip strength	32.6 ± 6.4	32.4 ± 7.5	0.8694	34.9 ± 6.7	31.4 ± 7.3	0.0091
WOMAC at baseline						
Pain	1.82 ± 1.20	3.32 ± 2.69	< 0.0001	–	–	–
Physical function	–	–	–	4.85 ± 7.69	7.20 ± 7.58	0.1132
Women						
N	97	274		58	346	
Age	68.1 ± 12.6	72.4 ± 8.6	0.0022	68.1 ± 11.1	73.2 ± 8.2	0.0015
BMI	22.4 ± 3.2	24.0 ± 3.6	< 0.0001	22.3 ± 3.2	23.6 ± 3.6	0.0066
Grip strength	22.9 ± 7.2	19.8 ± 4.9	0.0002	23.7 ± 7.4	19.7 ± 5.4	0.0002
WOMAC at baseline						
Pain	1.84 ± 1.18	3.68 ± 2.90	< 0.0001	–	–	–
Physical function	–	–	–	3.33 ± 4.32	8.99 ± 9.54	< 0.0001

Values are the means ± standard deviation.
BMI, body mass index; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

knee OA. Results were similar to findings without adjustment for treatment of knee OA (Supplementary Table 2 available online at http://informahealthcare.com/doi/abs/10.3109/14397595.2014.883055). In addition, we examined associations of age, BMI, grip strength and severity of knee OA with worsening pain and physical functional disability in subjects with pain and physical functional disability at baseline (Supplementary Table 3 available online at http://informahealthcare.com/doi/abs/10.3109/14397595.2014.883055). Multiple logistic regression analysis showed that weaker grip strength was a risk factor for worsening pain, whereas KL 3/4 knee OA was a risk factor for worsening physical functional disability (Supplementary Table 4 available online at http://informahealthcare.com/doi/abs/10.3109/14397595.2014.883055).

Discussion

This is the first longitudinal population-based study to examine the onset, resolution and worsening of pain and physical functional disability using WOMAC. We also clarified the associations of age, BMI, grip strength and knee OA with the onset, resolution and worsening of pain and physical functional disability.

Our previous study showed that onset of knee pain during 3 years was approximately 20% and 30% in men and women, respectively [24]. The Chingford study also showed that more than 10% women had onset of pain during 2 years [25]. However, in these previous studies, knee pain was defined as present or absent, rather than as an established measure of pain such as WOMAC. In addition, in our previous study, we did not examine resolution of pain. In the present study, we found that 35% of men and women had onset of pain. These values were higher than onset values obtained from questionnaires in our previous study [24], indicating that WOMAC may be more powerful for detecting pain than questionnaires regarding only the presence or absence of pain. We also found that pain disappeared in approximately 20% men and 25% women using WOMAC. The Chingford study previously showed that knee pain disappeared in approximately 40% of Caucasian women during 2 years using a questionnaire on the presence and absence of pain [25], which is higher than the values

Table 4. Association of onset of pain and physical functional disability with age, BMI, grip strength, and KL grade.

	Onset of pain			Onset of physical functional disability		
	Adjusted OR	95% CI	p value	Adjusted OR	95% CI	p value
Men						
Age (+ 1 year)	–	–	–	1.05	1.02–1.08	0.0011
BMI (+ 1kg/m^2)	–	–	–	–	–	–
Grip strength (+ 1kg)	–	–	–	1.01	0.97–1.04	0.628
KL grade						
KL 0/1	–	–	–	1		
KL 2	–	–	–	1.02	0.60–1.72	0.9504
KL 3/4	–	–	–	2.7	1.14–6.69	0.0274
Women						
Age (+ 1 year)	1.02	1.003–1.04	0.023	1.05	1.03–1.07	< 0.0001
BMI (+ 1kg/m^2)	1.08	1.03–1.15	0.0047	1.08	1.02–1.14	0.0141
Grip strength (+ 1kg)	0.99	0.96–1.02	0.4977	0.96	0.92–0.99	0.0152
KL grade						
KL 0/1	1			1		
KL 2	1.09	0.74–1.61	0.6593	0.84	0.56–1.25	0.4035
KL 3/4	1.42	0.79–2.55	0.2337	1	0.54–1.82	0.9894

Multiple logistic regression analysis was used with significant variables ($p < 0.01$) in univariate models as explanatory variables.
BMI, body mass index; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

found in the present study. This discrepancy between our study and the Chingford study may be partly explained by age differences in addition to different estimations for pain and racial differences, because mean age was 52 years in the Chingford study compared with 67 years in the present study. Furthermore, we first found that approximately 40% men and women had onset of physical functional disability and approximately 15% men and women had resolution of physical functional disability. To our knowledge, no other community-based studies have described longitudinal patterns of physical functional disability, and the present study was the first to clarify the onset and resolution of physical functional disability using WOMAC.

Pain is the principal clinical symptom of knee OA [5], but, although much effort has been devoted to defining knee pain, the correlation with radiographic severity of the knee OA is not as strong as one would expect [2,6–8]. In the present study, we examined onset of pain according to KL grade using WOMAC. In men and women without knee OA (KL 0/1), more than 30% subjects had onset of pain. In addition, 50% of men and women with KL 3/4 knee OA had onset of pain, meaning that 50% did not have onset of pain despite having severe radiographic knee OA. In fact, in the present study, radiographic knee OA was not significantly associated with onset of pain in men, and after adjustment, the significant association of knee OA with onset of pain disappeared in women. These findings indicate that pain may arise from a variety of structures other than joint cartilage, such as menisci, synovium, ligaments, bursae, bone and bone marrow [26–30]. In addition, in the present study, the risk for onset of pain was higher with higher BMI rather than knee OA in women, indicating knee pain may be prevented by reducing obesity.

In the present study, we also examined the association of knee OA with the resolution of pain, and found that around 30% of men and women without knee OA had resolution of knee pain, which was a similar rate to onset of pain, and only 7% of men and 15% of women with severe knee OA had resolution of knee pain. These findings indicate that around 90% of subjects with severe knee OA had continuous knee pain. There were significant associations of resolution of pain with KL grade. Considering the results of onset of pain, severe knee OA may lead to difficulties with resolution of pain rather than onset of pain, particularly in men. In addition, after adjustment, resolution of pain was significantly associated with lower BMI and higher grip strength, which is a useful marker of muscle function and sarcopenia [15], rather than radiographic knee OA, indicating that improvement of obesity and performing muscle exercises may help make pain disappear. In addition, the significant association of BMI and grip strength remained after adjustment for treatment of knee OA, indicating that reducing obesity and performing muscle exercises may be as important as treatment to achieve resolution of pain due to knee OA.

We also found that severe knee OA was a risk factor for physical functional disability, particularly in men, despite the finding that severe knee OA was not significantly associated with onset of pain in men. Severe knee OA was not significantly associated with onset of physical functional disability after adjustment for age in women, despite the finding that severe knee OA was significantly associated with onset of pain. This discrepancy between gender may be partly explained by the idea that women are more susceptible to pain. In fact, our previous study showed that the prevalence of knee pain in women with KL 0/1, 2 and 3/4 knee OA was significantly higher than that in men with KL 0/1, 2 and 3/4 knee OA, respectively[2]. In addition, risk factors for onset of physical functional disability were higher BMI and weaker grip strength rather than knee OA in women in the present study. Grip strength is a useful marker of muscle function and sarcopenia [15]. A previous study also showed that grip strength is related to total muscle [19]. Results in the present study indicate that onset of physical functional disability may be prevented by improvement of obesity and muscle exercises.

In the present study, physical functional disability disappeared in 20% of women without knee OA, whereas physical functional disability disappeared only in 5% of women with severe knee OA. The association of knee OA with resolution of physical functional

Table 5. Association of resolution of pain and physical functional disability with age, BMI, grip strength, and KL grade.

	Resolution of pain			Resolution of physical functional disability		
	Adjusted OR	95% CI	p value	Adjusted OR	95% CI	p value
Men						
Age (+ 1 year)	–	–	–	0.95	0.90–0.9985	0.0443
BMI (+ 1kg/m^2)	0.92	0.80–1.04	0.1994	–	–	–
Grip strength (+ 1kg)	–	–	–	1.02	0.96–1.09	0.526
KL grade						
KL 3/4	1			–	–	–
KL 2	2.37	0.52–16.8	0.3042	–	–	–
KL 0/1	5.18	1.32–34.6	0.0378	–	–	–
WOMAC at baseline						
Pain	0.63	0.46–0.80	0.001	–	–	–
Physical function	–	–	–	–	–	–
Women						
Age (+ 1 year)	0.99	0.96–1.02	0.6031	0.98	0.95–1.02	0.4081
BMI (+ 1kg/m^2)	0.88	0.80–0.96	0.0034	0.93	0.84–1.02	0.1358
Grip strength (+ 1kg)	1.08	1.02–1.14	0.014	1.09	1.02–1.16	0.0123
KL grade						
KL 3/4	1			1		
KL 2	1.34	0.66–2.79	0.4312	3.04	1.15–9.62	0.0362
KL 0/1	1.71	0.79–3.77	0.1797	2.52	0.89–8.34	0.0997
WOMAC at baseline						
Pain	0.66	0.53–0.78	< 0.0001	–	–	–
Physical function	–	–	–	0.87	0.78–0.93	0.0009

Multiple logistic regression analysis was used with significant variables ($p < 0.01$) in univariate model as explanatory variables.

BMI, body mass index; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index; KL, Kellgren Lawrence grade.

disability remained significant after adjustment. This means that in women without knee OA, pain may occur, but it may disappear more easily. In addition, grip strength was also associated with resolution of physical functional disability after adjustment, indicating that muscle exercises may help make physical functional disability disappear.

The present study showed gender differences in the associations of knee OA with pain and physical functional disability. In women, knee OA was significantly associated with onset of pain and physical functional disability as well as their resolution, whereas in men, there were no significant association of knee OA with onset of pain and resolution of physical functional disability. Our previous cross-sectional study also showed that the odds ratio of knee pain for KL 3/4 knee OA was approximately twice as high in women as in men[2]. These findings may be partly explained by the lower muscle mass in women compared with men. In men, muscular strength may obscure the associations of knee OA with pain and physical functional disability.

In conclusion, the present longitudinal study revealed the onset rate of pain and physical functional disability as well as their resolution rate using WOMAC. In addition, severe knee OA was significantly associated with onset of pain and physical functional disability as well as their resolution, particularly in women. Furthermore, we also clarified that BMI and grip strength were associated with onset of pain and physical functional disability as well as their resolution in women.

Acknowledgements

This study was supported by Grants-in-Aid for Scientific Research (S19109007, B20390182, C20591737, C20591774), for Young Scientists (A18689031), and for Exploratory Research (19659305) from the Japanese Ministry of Education, Culture, Sports, Science and Technology, H17-Men-eki-009, H18-Choujyu-037, H20-Choujyu-009, H21-Chouju-Wakate-011 and H22-Chouju-Wakate-007 from the Ministry of Health, Labor and Welfare, Research Aid from the Japanese Orthopaedic Association (JOA-Subsidized Science Project Research 2006-1 & 2010-2), and Grant No.166 from the Japan Orthopaedics and Traumatology Foundation.

The authors thank Dr. Yamamoto, Dr. Ishibashi, Dr. Anamizu and members of Department of Orthopaedics, and Mr. Kutsuma and other members of Department of Radiology at Tokyo Metropolitan Geriatric Medical Center; Mrs. Tomoko Takijiri and other members of the Public Office in Hidakagawa Town; and Mrs. Tamako Tsutsumi, Mrs. Kanami Maeda and other members of the Public Office in Taiji Town, for their assistance in the location and scheduling of participants for examinations.

Conflict of interest

None.

References

1. Sharma L, Kapoor D. Epidemiology of osteoarthritis. In: Moskowitz RW, Altman RD, Hochberg MC, Buckwalter JA, Goldberg VM, editors. Osteoarthritis: Diagnosis and Medical/Surgical Management. 4th ed. Philadelphia: Lippincott Williams & Wilkins; 2007. pp. 3–26.
2. Muraki S, Oka H, Akune T, Mabuchi A, En-yo Y, Yoshida M, et al. Prevalence of radiographic knee osteoarthritis and its association with knee pain in the elderly of Japanese population-based cohorts: The ROAD study. Osteoarthritis Cartilage. 2009;17(9):1137–43.
3. Yoshimura N, Muraki S, Oka H, Mabuchi A, En-yo Y, Yoshida M, et al. Prevalence of knee osteoarthritis, lumbar spondylosis and osteoporosis in Japanese men and women: The Research on Osteoarthritis/osteoporosis Against Disability (ROAD). J Bone Miner Metab. 2009;27(5):620–8.
4. Ministry of Health, Labour and Welfare. The outline of the results of National Livelihood Survey 2007. August 2013. Available at http://www.mhlw.go.jp/toukei/list/20-19-1.html.
5. Linaker CH, Walker-Bone K, Palmer K, Cooper C. Frequency and impact of regional musculoskeletal disorders. Baillieres Clin Rheumatol. 1999;13(2):197–215.
6. Duncan R, Peat G, Thomas E, Hay E, McCall I, Croft P. Symptoms and radiographic osteoarthritis: not as discordant as they are made out to be? Ann Rheum Dis. 2007;66(1):86–91.
7. Hannan MT, Felson DT, Pincus T. Analysis of the discordance between radiographic changes and knee pain in osteoarthritis of the knee. J Rheumatol. 2000;27(6):1513–7.
8. Neogi T, Felson D, Niu J, Nevitt M, Lewis CE, Aliabadi P, et al. Association between radiographic features of knee osteoarthritis and pain: results from two cohort studies. BMJ. 2009;339:b2844.
9. Bellamy N, Buchanan WW, Goldsmith CH, Campbell J, Stitt LW. Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. J Rheumatol. 1988;15(12):1833–40.
10. Thumboo J, Chew LH, Soh CH. Validation of the Western Ontario and McMaster University osteoarthritis index in Asians with osteoarthritis in Singapore. Osteoarthritis Cartilage. 2001;9(5):440–6.
11. Woo J, Lau E, Lee P, Kwok T, Lau WC, Chan C, et al. Impact of osteoarthritis on quality of life in a Hong Kong Chinese population. J Rheumatol 2004;31(12):2433–8.
12. Dillon CF, Rasch EK, Gu Q, Hirsch R. Prevalence of knee osteoarthritis in the United States: arthritis data from the Third National Health and Nutrition Examination Survey 1991-94. J Rheumatol. 2006;33(11): 2271–9.
13. Jordan JM, Helmick CG, Renner JB, Luta G, Dragomir AD, Woodard J, et al. Prevalence of knee symptoms and radiographic and symptomatic knee osteoarthritis in African Americans and Caucasians: the Johnston County Osteoarthritis Project. J Rheumatol. 2007;34(1):172–80.
14. Yoshida S, Aoyagi K, Felson DT, Aliabadi P, Shindo H, Takemoto T. Comparison of the prevalence of radiographic osteoarthritis of the knee and hand between Japan and the United States. J Rheumatol. 2002;29(7):1454–8.
15. Roubenoff R. Sarcopenia: a major modifiable cause of frailty in the elderly. J Nutr Health Aging. 2000;4(3):4140–2.
16. Bohannon RW. Hand-grip dynamometry predicts future outcomes in aging adults. J Geriatr Phys Ther. 2008;31(1):3–10.
17. Sirola J, Rikkonen T, Tuppurainen M, Jurvelin JS, Kroger H. Association of grip strength change with menopausal bone loss and related fractures: a population based follow-up study. Calcif Tissue Int. 2006;78(4):218–26.
18. Kerr A, Syddall HE, Cooper C, Turner GF, Briggs RS, Sayer AA. Does admission grip strength predict length of stay in hospitalised older patients? Age Ageing 2006;35(1):82–4.
19. Wind AE, Takken T, Helders PJ, Engelbert RH. Is grip strength a predictor for total muscle strength in healthy children, adolescents, and young adults? Eur J Pediatr. 2010;169(3):281–7.
20. Yoshimura N, Muraki S, Oka H, Kawaguchi H, Nakamura K, Akune T. Cohort profile: Research on osteoarthritis/osteoporosis against disability (ROAD) study. Int J Epidemiol. 2010;39: 988–95.
21. Kellgren JH, Lawrence JS (eds.). The Epidemiology of Chronic Rheumatism: Atlas of Standard Radiographs of Arthritis. Oxford, England: Blackwell Scientific; 1963.
22. Barr S, Bellamy N, Buchanan WW, Chalmers A, Ford PM, Kean WF, et al. A comparative study of signal versus aggregate methods of outcome measurement based on the WOMAC Osteoarthritis Index. J Rheumatol 1994;21(11):2106–12.
23. Hashimoto H, Hanyu T, Sledge CB, Lingard EA. Validation of a Japanese patient-derived outcome scale for assessing total knee arthroplasty: comparison with Western Ontario and McMaster Universities osteoarthritis index (WOMAC). J Orthop Sci. 2003; 8(3):288–93.
24. Muraki S, Akune T, Oka H, Ishimoto Y, Nagata K, Yoshida M, et al. Incidence and risk factors for radiographic knee osteoarthritis and knee pain in Japanese men and women: a longitudinal population-based cohort study. Arthritis Rheum. 2012;64(5):1447–56.
25. Soni A, Kiran A, Hart DJ, Leyland KM, Goulston L, Cooper C, et al. Prevalence of reported knee pain over twelve years in a community-based cohort. Arthritis Rheum 2012;64(4):1145–52.
26. Saito T, Koshino T. Distribution of neuropeptides in synovium of the knee with osteoarthritis. Clin Orthop Relat Res. 2000;376: 172–82.

27. Bollet AJ. Edema of the bone marrow can cause pain in osteoarthritis and other diseases of bone and joints. Ann Intern Med. 2001;134(7):591–3.
28. Teichtahl AJ, Wluka AE, Morris ME, Davis SR, Cicuttini FM. The relationship between the knee adduction moment and knee pain in middle-aged women without radiographic osteoarthritis. J Rheumatol. 2006;33(9):1845–8.
29. Thorp LE, Sumner DR, Wimmer MA, Block JA. Relationship between pain and medial knee joint loading in mild radiographic knee osteoarthritis. Arthritis Rheum. 2007;57(7):1254–60.
30. Felson DT, Niu J, Guermazi A, Roemer F, Aliabadi P, Clancy M, et al. Correlation of the development of knee pain with enlarging bone marrow lesions on magnetic resonance imaging. Arthritis Rheum. 2007;56(9):2986–92.

Supplementary material available online

Supplementary Tables 1–4.

Japan College of Rheumatology
MODERN RHEUMATOLOGY

http://informahealthcare.com/mor
ISSN 1439-7595 (print), 1439-7609 (online)

Mod Rheumatol, 2014; 24(2): 250–257

DOI: 10.3109/14397595.2013.854063

informa healthcare

ORIGINAL ARTICLE

Development and evaluation of a video exercise program for locomotive syndrome in the elderly

Hiroshi Hashizume[1], Noriko Yoshimura[2], Keiji Nagata[1], Nobuyuki Miyazaki[1], Yuyu Ishimoto[1], Ryoko Nishiyama[1], Hiroyuki Oka[2], Hiroshi Yamada[1], and Munehito Yoshida[1]

[1]*Department of Orthopaedic Surgery, Wakayama Medical University, Wakayama City, Wakayama, Japan, and* [2]*Department of Joint Disease Research, 22nd Century Medical and Research Center, Graduate School of Medicine, The University of Tokyo, Tokyo, Japan*

Abstract

Objectives. To develop and evaluate an exercise program that the elderly could sustainably perform in the community or at home to recover from locomotive syndrome.
Methods. We produced 2 types of teaching media, video and pamphlet, describing 10 physical and mobility training exercises. The pilot study examined changes in pulse rate, percutaneous oxygen saturation (SpO_2), and the Borg scale rating of perceived exertion in 20 elderly volunteers. Separately, 120 elderly subjects were recruited and divided into 3 groups according to the teaching medium (video, group V; pamphlet, group P; none, group C). Before and 3 months after the intervention, visual analog scale (VAS) scores of low back and knee pain, single-leg standing time, 6-m walking time, Roland–Morris Disability Questionnaire, Oswestry Disability Index, Short Form-8, and 25-question Geriatric Locomotive Function Scale were evaluated.
Results. Pulse-rate changes before and after exercise did not exceed 20 %, and SpO_2 changes were within 4 points in all cases. The Borg scale ranged between 11 and 14. The intergroup comparison revealed the advantage of the video program in improving the VAS of low back pain, left-leg standing time, and 6-m walking time.
Conclusion. A video exercise program can potentially aid recovery from locomotive syndrome in the elderly.

Keywords

DVD video, Elderly, Exercise program, Locomotive syndrome, Low back pain

History

Received 14 November 2012
Accepted 6 March 2013
Published online 30 March 2013

Introduction

Population aging is occurring in countries worldwide, but it is most advanced in highly developed countries. The population of Japan in particular is aging very rapidly. According to an estimate by the Ministry of Internal Affairs and Communications released on October 1, 2007, 29,005,000 people (22.7 % of the total population) in Japan were 65 years old or older [1]. The United Nations has therefore labeled Japan a "superaged" society. Aging is associated with an increased risk of problems related to physical mobility. By 2006, the number of elderly persons in Japan needing nursing care had increased to 4,300,000; orthopedic problems are unquestionably one of the main reasons for this need [2]. According to the Comprehensive Survey of Living Conditions conducted in 2007 by the Japan Ministry of Health, Labour and Welfare, the most frequent symptom in both men and women 65 years old or older was low back pain [3]. Joint disease is also a major cause of the need for long-term care; in a large-scale population-based cohort study, the number of patients in Japan with knee osteoarthritis (KOA) was estimated to be approximately 25 million [4].

To increase society's awareness of this problem, the Japanese Orthopaedic Association (JOA) has proposed the concept of *locomotive syndrome*, a condition in which the elderly receive care services, or are at high risk of soon requiring care services, because of difficulty with physical mobility [2, 5]. The earliest possible intervention is required to prevent the need for long-term care among individuals with locomotive syndrome.

Many reports indicated that exercise is effective for most disorders affecting mobility, including low back pain and knee disease [6, 7]. However, few reports have investigated the efficacy of exercise for the elderly, especially from the point of view of preventing locomotive syndrome. Because the elderly often have multiple diseases that affect their mobility, studies to develop tools for the early detection of locomotive syndrome are ongoing. Investigations of specific methods for teaching exercise to the elderly are also underway.

The purposes of this study are to (1) develop an exercise program that the elderly could sustainably perform in the community or at home, (2) investigate which medium of exercise instruction (video or pamphlet) is superior, and (3) determine the parameter that is most useful for evaluating the effectiveness of this intervention for locomotive syndrome.

Methods

For this study, "elderly" was defined according to the Japan Ministry of Health, Labour and Welfare's definition of 65 years old or older. The study was conducted after approval from the ethics review board and consent from the participants were obtained.

Correspondence to: Hiroshi Hashizume, Department of Orthopaedic Surgery, Wakayama Medical University, 811-1 Kimiidera, Wakayama City, Wakayama 649-6122, Japan. Tel: +073-441-0645. Fax: +073-448-3008. E-mail: hashizum@wakayama-med.ac.jp

Development of the exercise program for the elderly

Exercise program

Ten types of exercises that an elderly person could perform without excess load on the musculoskeletal system or cardiopulmonary function were selected from widely known physical and mobility training exercises. The exercises were combined into a single exercise program comprising 2 distinct parts:

(A) Mobility training for fall prevention (Fig. 1a)

1. Stepping (40 s)
2. Single-leg standing with eyes open (10 s/cycle × 4)
3. Squatting (10 s/cycle × 10)
4. Quadriceps femoris training (5 s/bilateral side × 5)

(B) Muscle training to prevent/improve low back pain (Fig. 1b)

1. Muscle training of the hips and pelvis (10 s/cycle × 8)
2. Exercises for back flexibility (10 s/cycle × 5)
3. Abdominal muscle training (10 s/cycle × 5)
4. Back muscle training (5 s/cycle × 3)
5. Stretching of the lumbar spine (30 s/cycle × 2)
6. Rounding the back like a cat (10 s)

Teaching materials

Two types of teaching media were produced (Fig. 2). One was a DVD video of exercise demonstration by 2 instructors with background music and commentary. The other was a pamphlet including the same content as the DVD video but consisting of photographs and descriptions. In the video, the rhythm was regulated so that 4 beats of the background music lasted for 5 s.

Estimation of the physical load from the DVD video exercise

Twenty volunteers (age range 65–88 years) who used a day hospital service were asked to perform the video exercises for 15 min. Changes in pulse rate and percutaneous oxygen saturation (SpO_2) before (within 5 min of starting) and after (within 60 s of finishing) the exercise were measured. The Borg scale rating of perceived exertion (RPE, range 6–20) was also recorded to measure the subjective intensity level of the physical activity [8].

Evaluation of the efficacy of the exercise program

Participants and sampling in groups

One hundred twenty elderly residents (age range 65–85 years, mean 72.2 years) of Hashimoto City were recruited by open

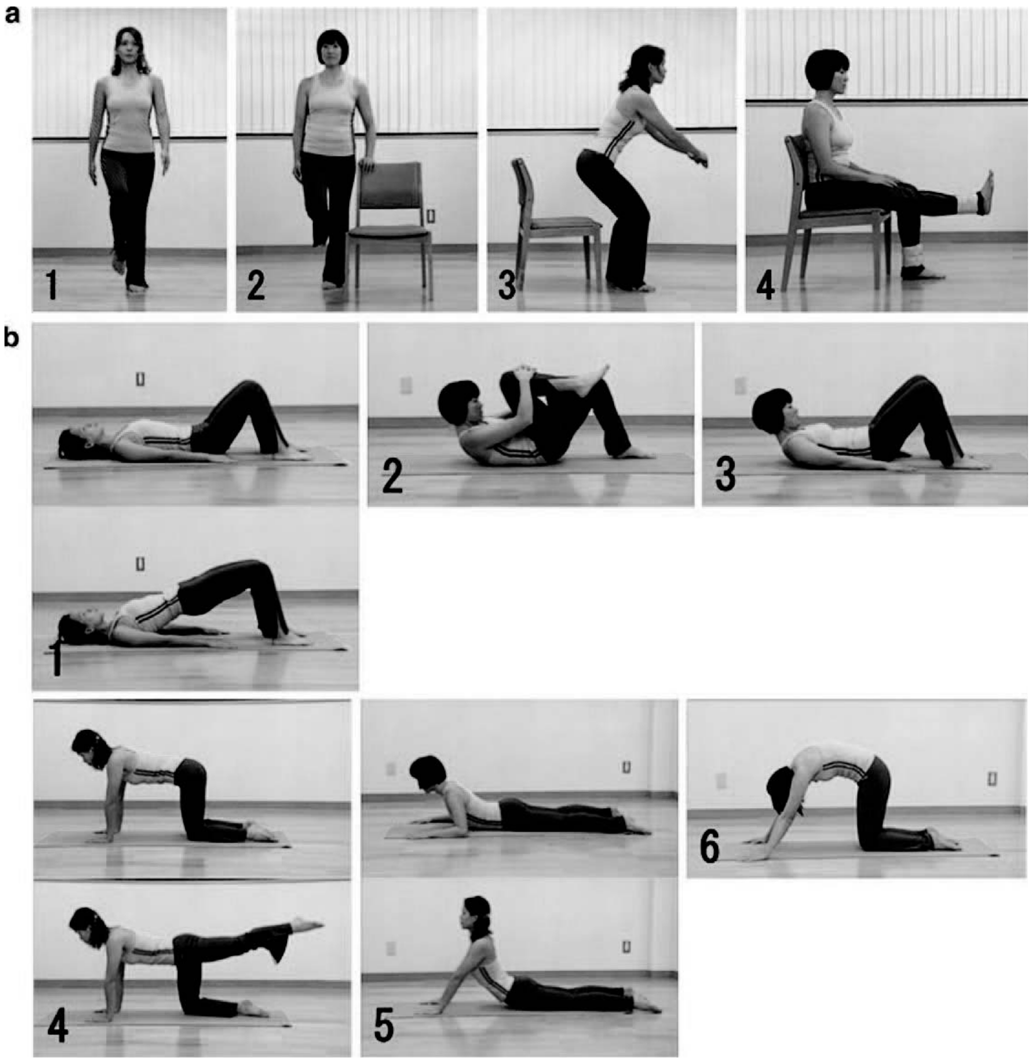

Fig. 1 Exercise program for the elderly. (a) Mobility training for fall prevention: (1) stepping, (2) single-leg standing with eyes open, (3) squatting, and (4) quadriceps femoris training. (b) Muscle training to prevent/improve low back pain: (1) muscle training of the hips and pelvis, (2) exercises for back flexibility, (3) abdominal muscle training, (4) back muscle training, (5) stretching of the lumbar spine, and (6) rounding the back like a cat

Fig. 2 Two types of teaching media produced for the participants. (a) DVD jacket cover. (b) Example of the instructions in the pamphlet: (1) stepping (*top*), (2) single-leg standing with eyes open (*middle*), and (3) squatting (*bottom*)

invitation. Hashimoto City is located between the mountains and a dormitory town of Osaka. In 2008, elderly people constituted 22.3 % of the approximately 69,000-resident population.

The participants were divided randomly into the following 3 groups by a member of the city staff: (1) group V participants performed the exercises while watching the video; (2) group P participants performed the exercises while reading the pamphlet; and (3) group C participants did not perform the exercises. Participants were allowed to change groups when requested because of a family relationship or friendship. Finally, there were 43, 41, and 36 participants in groups V, P, and C, respectively. Participants in groups V and P were instructed to perform all exercises twice a day. The period of intervention was set at 3 months.

Radiographic assessment

All participants underwent radiographic examination at the start of the intervention to assess degenerative changes in their knee joints or lumbar spine. KOA and lumbar spondylosis (LS) were defined as grade ≥2 on the Kellgren–Lawrence scale [9]; i.e., radiographic findings of definite osteophytes and definite narrowing of the joint space or intervertebral space were defined as grade 2. Osteoporosis (OP) of the lumbar spine was defined as sparse or absent longitudinal trabeculae in the vertebral body in accordance with the criteria proposed by the Japanese Society for Bone and Mineral Research [10]. Vertebral fracture was assessed by a quantitative method using lateral radiographs of the lumbar spine (L1–L5), according to the Japanese Society of Bone and Mineral Research criteria [10]. Wedge appearance was defined as a site at which the anterior height of the vertebra was ≤75 % of the posterior height. Biconcave appearance occurred if the height of the central part of the vertebra was ≤80 % of that of the anterior or posterior parts of the vertebra. Crush appearance was indicated if the heights of the anterior, central, and posterior parts of an axial vertebra were all reduced to ≤80 % of the normal values.

Clinical assessment

Clinical assessments of the participants were performed at the start of the intervention. Anthropometric measurements included height, weight, and body mass index [BMI; weight (kg)/height (m^2)]. To evaluate physical performance, the single-leg standing time for each leg was measured using a stopwatch (upper limit, 60 s). Six-meter walking times with normal steps and quick steps were also measured using a stopwatch. These measurements were performed by members of the local government staff who were blinded to the intervention groups. At the same time, the participants completed several types of self-report questionnaires. Presence of pain was assessed by a questionnaire asking the participants if they had experienced low back pain or knee pain lasting more than 24 h within the previous month. The participants were also asked to rate the intensity of their current pain pertaining to the lower back or knee joints by using a visual analog scale (VAS, range 0–100). For the assessment of functional disability, participants completed the Oswestry Disability Index (ODI, Japanese version; range 0–100) [11]; for the assessment of low back pain, the Roland–Morris Disability Questionnaire (RDQ, Japanese version; range 0–24) [11–13] was used. The participants completed the Short Form-8 health survey (SF-8, Japanese version) [14] for assessment of health-related quality of life. The physical component summary (PCS) and mental component summary (MCS) scores of this instrument were calculated using the norm-based scoring system [14]. The 25-question Geriatric Locomotive Function Scale (GLFS-25, Japanese version) was used to detect locomotive syndrome [15]. The GLFS-25 is a self-administered, relatively comprehensive measure consisting of 25 items. These 25 items are graded on a 5-point scale, ranging from no impairment (0 points) to severe impairment (4 points), and the scores are then added together to produce a total (range 0–100). We set the cutoff score for identifying locomotive syndrome at 16, according to the currently accepted criteria [15].

The same clinical assessments, excluding anthropometric measurements or the presence of pain, were performed at the end (after 12 weeks) of the intervention. In addition, the participants in groups V and P recorded their daily level of exercise during the intervention. When a subject performed all of the exercises once, a score of 2 was given. One point was given if some of the exercises were performed, and a score of 0 was given if the subject did not perform any exercises. Because the participants in the 2 groups were instructed to perform all of the exercises twice daily, the possible range of daily points was 0–4. The exercise achievement summary scale was calculated using the following formula: (sum of the daily points/4 $\times$ number of days) $\times$ 100.

Statistical analyses

JMP9 (SAS Institute Inc., Cary, NC, USA) and IBM SPSS Statistics 18 (International Business Machines Corp., Armonk, NY, USA) statistical software were used for the statistical analyses in this study. To compare the baseline data among the 3 groups, a chi-square test for independence was used for proportional variables (sex and prevalence). One-factor analysis of variance (ANOVA) was performed for parametric variables (age, VAS, single-leg standing time, and 6-m walking time). A Kruskal–Wallis rank test was performed for nonparametric data (RDQ, ODI, PCS, MCS, and GLFS-25). For intragroup comparisons between baseline and 3 months after the intervention, a paired *t* test was used for parametric data (age, VAS, single-leg standing time, and 6-m walking time) and a Wilcoxon signed-rank test was used for nonparametric data (RDQ, ODI, PCS, MCS, and GLFS-25). A Mann–Whitney *U* test was applied to compare the exercise achievement summary scale scores between groups V and P. The intervention effect (the change of each parameter) was also compared. In advance of the comparison, split-plot ANOVA was performed to assess inter- and intragroup differences by using repeated values of VAS; single-leg standing time; 6-m walking time; and PCS, MCS, RDQ, ODI, and GLFS-25 scores as objective factors and group as an explanatory factor. Mauchly's sphericity test was used to validate the equality of the variances for repeated measures of the 3 groups. Subsequently, Scheffé's *F* post hoc pairwise multiple-comparison test was performed to assess the significance of the mean differences between the groups. In cases in which the baseline parameters significantly differed among the groups, analysis of covariance (ANCOVA) was applied in which the baseline value was added as a covariate. A value of $p < 0.05$ was considered significant.

Results

Physical load of the DVD video exercise

All 20 elderly participants with locomotive disability and/or concomitant internal disease completed the 15-min DVD video exercise program. Pulse-rate changes before and after exercise did not exceed 20 %, and SpO_2 changes were within 4 points in all cases. The RPE scores were 11 (light), 12, 13 (somewhat hard), and 14 for 5, 12, 2, and 1 participants, respectively. No participants had a score of 15 (hard) or higher for the intensity of the exercises (Table 1).

Efficacy of the exercise program

Table 2 presents the age, anthropometric measurements, prevalence of bone and joint diseases, and SF-8 summary scores (i.e.,

Table 1. Physical load of the DVD video exercise in 20 volunteers

			Concomitant chronic diseases		Pulse rate (bpm)		SpO_2 (%)		
No.	Age (years)	Sex	Musculoskeletal disease	Internal disease	Before EX	After EX	Before EX	After EX	RPE
1	78	Female	LBP	HT, bronchial asthma	74	78	95	95	12
2	71	Female	LBP	DM	88	84	93	92	12
3	69	Female	LBP	HT	92	91	96	96	13
4	73	Female	LBP		78	76	95	93	11
5	66	Female		Hyperlipemia	88	84	92	92	12
6	74	Female	KOA	HT	84	90	96	94	12
7	66	Male		HT, cerebral infarction	89	92	95	95	11
8	88	Male	LBP	HT, arrhythmia	81	83	94	92	12
9	65	Male	LSS		76	88	95	92	12
10	80	Male		LBP, KOA arrhythmia	78	92	95	91	14
11	83	Female	LBP	Cerebral infarction	77	79	97	97	11
12	82	Male	LBP	HT	80	84	97	96	12
13	80	Male	LBP	Parkinson's disease	80	88	94	96	12
14	69	Male	LSS	HT	85	87	96	96	12
15	73	Male	LBP	DM	72	68	97	95	11
16	78	Female	LBP	HT, arrhythmia	85	89	93	93	12
17	77	Male	LBP	Vertigo	63	72	97	97	11
18	79	Male		HT, bronchitis, angina pectoris	69	72	95	97	12
19	75	Male	LBP	Bronchial asthma	82	96	90	90	13
20	70	Male	LBP, HOA		86	86	97	95	12

Perceived exertion ratings of 12–14 suggest that physical activity was performed at a moderate level of intensity

LBP low back pain, *LSS* lumbar spinal stenosis, *KOA* knee osteoarthritis, *HOA* hip osteoarthritis, *HT* hypertension, *DM* diabetes mellitus, *bpm* beats per minute, *EX* exercise, SpO_2 percutaneous oxygen saturation, *RPE* Borg rating of perceived exertion scale (range 6–20); RPE 11, "light" intensity; RPE 13, "somewhat hard" intensity; RPE 15, "hard" intensity

Table 2. Characteristics of 120 elderly participants

	Men	Women
Number of subjects	32	88
Age (years)	74.1 ± 5.4	71.6 ± 4.3
Height (cm)	164.5 ± 4.7	151.4 ± 4.9
Body weight (kg)	67.2 ± 9.1	53.1 ± 7.7
Body mass index (kg/m^2)	24.8 ± 2.6	23.1 ± 3.0
Prevalence		
Musculoskeletal pain		
Low back pain	26/31 (83.9 %)	58/86 (67.4 %)
Knee pain	11/31 (35.5 %)	32/86 (37.2 %)
Radiographic findings		
LS	28/31 (90.3 %)	71/86 (82.6 %)
KOA	16/32 (48.4 %)	67/86 (77.9 %)
OP of the lumbar spine	1/31 (3.2 %)	38/86 (44.2 %)
VF of the lumbar spine	1/31 (3.2 %)	11/86 (12.8 %)
Locomotive syndrome	8/31 (25.8 %)	36/88 (40.9 %)
Short Form-8 summary scores		
PCS	46.1 (40.9–49.3)	45.3 (41.2–49.6)
MCS	52.1 (49.6–55.7)	53.0 (48.3–55.3)

PCS and MCS presented as median (25–75 %). Locomotive syndrome was indicated by the 25-question Geriatric Locomotive Function Scale when the total score was ≥16 points

LS lumbar spondylosis, *KOA* knee osteoarthritis, *OP* osteoporosis, *VF* vertebral fracture, *PCS* physical component scale, *MCS* mental component scale

Table 3. Characteristics of the participants in the 3 intervention groups

	Group V	Group P	Group C
Number of subjects	43	41	36
Age (years)	72.9 ± 5.1	70.9 ± 3.9	73.1 ± 4.9
Gender (male:female)	18:25*	7:34	7:29
Body mass index (kg/m^2)	23.5 ± 3.0	23.5 ± 2.6	23.5 ± 3.3
Prevalence			
Musculoskeletal pain			
Low back pain	32/42 (76.2 %)	30/40 (75.0 %)	22/35 (62.9 %)
Knee pain	15/42 (35.7 %)	15/41 (36.6 %)	12/36 (33.3 %)
Radiographic findings			
LS	36/40 (90.0 %)	32/41 (78.0 %)	31/36 (86.1 %)
KOA	25/40 (62.5 %)	30/41 (73.2 %)	27/36 (75.0 %)
OP of the lumbar spine	10/40 (25.0 %)	18/41 (43.9 %)	11/36 (30.6 %)
Locomotive syndrome	17/42 (40.5 %)	15/41 (36.6 %)	12/36 (33.3 %)

Locomotive syndrome was indicated by the 25-question Geriatric Locomotive Function Scale when the total score was ≥16 points

Group V video exercise group, *Group P* pamphlet exercise group, *Group C* control group, *LS* lumbar spondylosis, *KOA* knee osteoarthritis, *OP* osteoporosis

*$p < 0.05$

PCS and MCS) in men and women. These data are used to verify the characteristics of the participants in the "Discussion."

The participants' characteristics by group are presented in Table 3. The mean age and BMI of the participants did not differ significantly among the 3 groups. There was a bias in the sex distribution among the 3 groups ($p = 0.0453$). At the start of the intervention, the prevalence of low back and knee pain did not differ significantly among the groups. No significant differences were observed among the groups regarding the prevalence of LS, KOA, and OP, although there was a tendency of a relatively higher prevalence of OP in group P. In total, 17 of 42 participants in group V, 15 of 41 participants in group P, and 12 of 36 participants in group C were diagnosed with locomotive syndrome. The prevalence of locomotive syndrome was not significantly different among the groups.

The follow-up rates (proportion of the participants who completed the 3-month intervention) were 88.4, 90.2, and 83.3 % for groups V, P, and C, respectively. One woman in group P withdrew from the study because she sustained a vertebral body fracture during her daily activities. Furthermore, 1 woman in group C withdrew because she was awaiting surgery for cervical spondylotic myelopathy. Another 13 participants withdrew from the study for personal reasons. No participants in group V or group P withdrew because of the difficulty of the exercise itself. The exercise achievement summary scale score in group V (median = 74.1 %, 25–75 percentile = 58.0–91.7 %) was significantly higher ($p = 0.0015$) than that in group P (median = 53.2 %, 25–75 percentile = 35.9–73.8 %). There was no significant difference in the exercise achievement summary scale score between men (median = 69.6 %, 25–75 percentile = 40.4–91.1 %) and women (median = 64.7 %, 25–75 percentile = 39.1–81.2 %).

Changes in the evaluation items before and after the intervention are presented in Table 4. Group V included more physically inferior participants than the other 2 groups at baseline. During the 3 months, different responses to the intervention were observed in each group. In group V, significant improvements were observed in the VAS score for low back pain, single-leg standing time (both right and left legs), 6-m walking time (both with normal steps and with quick steps), and PCS score. In group P, significant improvements were observed in the single-leg standing time (left leg) and PCS and RDQ scores. In group C, no significant change was observed in any parameter during the 3 months.

Thereafter, the changes in each parameter were compared among groups V, P, and C (Table 5). Split-plot ANOVA revealed a significant interaction for the VAS of low back pain, single-leg standing time (left leg), and 6-m walking time for both normal and quick steps among the 3 groups. The baseline values of the 6-m walking time (with both normal and quick steps) and PCS score were significantly different among the 3 groups. ANOVA revealed significant differences in changes in the VAS of low back pain, left-leg standing time, 6-m walking time (both with normal steps and with quick steps), and PCS score among the groups. Statistical differences were observed in these parameters excluding the PCS score after adjustment by the covariate (i.e., baseline value) in ANCOVA. Moreover, statistical differences were similarly observed in the same parameters (VAS of low back pain: $p = 0.0471$; left-leg standing time: $p = 0.0205$; 6-m walking time with normal steps: $p = 0.0155$; 6-m walking time with quick steps: $p = 0.0422$) when gender was added as a covariate.

During the 3 months, the numbers of locomotive syndrome participants who withdrew from the study were 0, 2, and 3 in groups V, P, and C, respectively. In total, 6 of 17 participants in group V, 3 of 13 participants in group P, and 0 of 9 participants in group C recovered from locomotive syndrome after the intervention.

Discussion

As stated in the "Introduction" the increasing number of elderly persons who need nursing care is becoming an urgent social issue in many countries. At the beginning of this study, we indicated 3 purposes for conducting an exercise intervention to recover from locomotive syndrome.

The first purpose of this study was to develop an exercise program that the elderly could sustainably perform in the community or at home. It was intended that the video exercise program in this study would be performed without difficulty by the elderly and would thus improve their physical performance and prevent the need for long-term care. Each exercise that we selected has been conventionally used for patients, depending on their condition. The

Table 4. Changes in the evaluation items before and after intervention

	Group V ($n = 38$)		Group P ($n = 37$)		Group C ($n = 30$)	
	Baseline	3 months later	Baseline	3 months later	Baseline	3 months later
Visual analog scales						
Low back pain	38.5 ± 22.3	25.6 ± 18.0**	32.7 ± 21.2	31.5 ± 27.7	28.2 ± 26.4	22.3 ± 24.3
Knee pain	19.5 ± 19.5	21.8 ± 23.2	19.8 ± 17.3	14.8 ± 15.7	21.6 ± 23.1	16.9 ± 17.5
Single-leg standing time						
Right leg (s)	33.7 ± 22.9	42.8 ± 21.8*	42.6 ± 22.7	42.4 ± 22.1	38.2 ± 25.0	38.9 ± 23.4
Left leg (s)	27.0 ± 22.5	39.3 ± 23.5**	37.7 ± 21.9	45.0 ± 19.3*	32.9 ± 23.4	34.9 ± 22.3
6-m walking time						
Normal steps (s)	5.7 ± 0.7	5.4 ± 0.9*	4.9 ± 1.1	5.3 ± 1.0*	5.1 ± 1.1	5.2 ± 1.0
Quick steps (s)	4.4 ± 0.6	4.2 ± 0.6**	3.8 ± 0.7	3.9 ± 0.7	4.1 ± 0.8	3.9 ± 0.6
Short Form-8 summary scores						
PCS	42.5 (38.6–47.9)	44.1 (40.4–49.1)*	45.1 (41.0–48.8)	47.9 (42.8–51.8)*	49.1 (44.8–52.1)	48.6 (43.5–52.7)
MCS	52.9 (49.0–55.7)	53.9 (48.3–56.7)	53.0 (49.3–56.3)	54.3 (51.4–56.4)	52.8 (47.2–55.2)	52.8 (48.0–55.2)
RDQ score	4.0 (2.0–9.0)	4.0 (0.0–11.0)	3.5 (0.0–7.3)	2.0 (0.0–6.5)*	2.0 (0.0–5.5)	1.0 (0.0–5.0)
ODI (% disability)	17.8 (7.2–30.6)	17.8 (6.7–30.6)	17.8 (8.9–23.9)	14.4 (5.0–24.4)	13.3 (3.3–22.2)	11.1 (2.8–21.7)
GLFS-25 score	14.0 (6.0–27.3)	10.0 (5.5–20)	10.0 (5.5–23)	7.0 (4.0–19.5)	10.0 (5.0–16.0)	9.0 (4.0–17.0)

Visual analog scales, single-leg standing time, and 6-m walking time presented as mean ± standard deviation. Short Form-8 summary scores, RDQ score, ODI, and GLFS-25 score presented as median (25–75 %)

Group V video exercise group, *Group P* pamphlet exercise group, *Group C* control group, *PCS* physical component scale, *MCS* mental component scale, *RDQ* Roland–Morris Disability Questionnaire, *ODI* Oswestry Disability Index, *GLFS-25* the 25-question Geriatric Locomotive Function Scale

*$p < 0.05$, **$p < 0.01$

first half of the program consists of quadriceps femoris exercise and fall-prevention exercises, which are reported to be effective for KOA [16]. The latter half of the program consists of exercises for low back pain. Many studies have confirmed the effectiveness of these exercises [6, 17]. The current exercise program was intended to improve general physical performance with the aim of preventing locomotive syndrome because the elderly often have multiple diseases affecting their mobility. During the development of the program, the first consideration was to avoid an excessive burden on the cardiopulmonary function of the participants. The pilot study, which examined the physical load on 20 elderly volunteers, demonstrated that pulse-rate changes before and after exercise did not exceed 20 % and that the SpO_2 change was within 4 points in all the cases. The RPE scores were 11–14 for all participants. These results confirmed that the video exercise program provided a moderate physical load for most of the elderly participants without imposing an excessive cardiopulmonary burden.

The second purpose of this study was to determine which medium of exercise instruction (video or pamphlet) is superior. We investigated the short-term efficacy of the exercise program with regard to physical performance in elderly participants and compared the effectiveness of the different teaching media. Several studies have used a video exercise program for frail elderly individuals [18, 19]. The superiority of video programs over written instructions has been reported for shoulder exercises [20] and for educating candidates for back surgery [21] and total knee arthroplasty [22]. Therefore, we expected that the video exercise program would relieve participants of body pain and improve their physical performance better than the pamphlet exercise program at the beginning of this study. In fact, the exercise achievement summary scale score in group V was significantly higher than that in group P. This finding indicated that the video exercise program provides greater motivation for participants than does the pamphlet exercise program. Moreover, intergroup comparisons of changes in the parameters after 3 months revealed statistically significant differences among the groups.

The third purpose of this study was to determine which parameter is most useful for evaluating the effectiveness of this intervention in preventing locomotive syndrome. We used the single-leg standing and 6-m walking tests as indices of physical performance to evaluate the effect of exercise on the elderly participants. The single-leg standing test has been reported to be a useful index for

Table 5. Intergroup comparison of the change of each parameter

	Interaction	Baseline value	Effect of intervention	
	Split-plot ANOVA *p* value	ANOVA *p* value	ANOVA *p* value	ANCOVA *p* value
Visual analog scales				
Low back pain	**0.027**	0.250	**0.037**	
Knee pain	0.266	0.892	0.182	
Single-leg standing time				
Right leg	0.150	0.154	0.150	
Left leg	**0.024**	0.069	**0.009**	
6-m walking time				
Normal steps	**<0.001**	**<0.001**	**<0.001**	**0.022**
Quick steps	**0.001**	**0.001**	**0.001**	**0.040**
Short Form-8 summary scores				
PCS	0.088	**0.016**	**0.014**	0.426
MCS	0.798	0.316	0.230	
RDQ score	0.436	0.454	0.099	
ODI (% disability)	0.803	0.669	0.297	
GLFS-25 score	0.347	0.690	0.508	

Values in bold are statistically significant

ANOVA analysis of variance, *ANCOVA* analysis of covariance, *PCS* physical component scale, *MCS* mental component scale, *RDQ* Roland–Morris Disability Questionnaire, *ODI* Oswestry Disability Index, *GLFS-25* the 25-question Geriatric Locomotive Function Scale examining elderly populations [23]. Moreover, gait velocity has been reported to be sensitive to changes in mobility in frail elderly individuals [23–25]. Although the observation period of this study was short, the values of the 2 measurements revealed significant improvement, at least in group V. These 2 measurements may be useful indices for evaluating short-term effects on physical performance (mobility and static balance) in elderly individuals.

This study had several limitations. First, the grouping of the participants was not perfectly randomized. Group V included more physically inferior participants than the other 2 groups. We permitted group changes as requested by the participants because they were recruited from a community-based population. It was difficult to place couples and friends in different groups without the risk of information leakage. The short period (3 months) of the intervention/observation was another limitation of this study. If the aim of the study is to prevent the need for care in elderly individuals, then a longer observation time is necessary. Further investigation is necessary regarding the long-term effects on society, such as changes in medical costs and the number of elderly individuals requiring nursing care. Regarding the static balance exercise, the significant improvement in the single-leg standing time after 3 months may be surprising especially because our exercise program contains only a short (i.e., 10 s/cycle × 4) single-leg standing exercise. The JOA and the Japanese Clinical Orthopaedic Association (JCOA) recommend the one-leg standing balance exercise for 1 min to prevent falls and hip fractures [26, 27]. A systematic review concerning falls prevention suggests that greater relative effects are observed in programs that include exercises that challenge balance (exercises conducted while standing in which people aim to stand with their feet closer together or on 1 leg, minimize the use of their hands to assist, and practice controlled movements of the center of gravity), use a higher intensity of exercise, and do not include a walking program [28]. A Cochrane review including 94 studies of balance exercise in the elderly suggests that the more effective programs ran 3 times a week for 3 months and involved dynamic exercise in standing [29]. We believe our results do not contradict the summary of the 2 systematic reviews. Moreover, we speculate that the improvement of our participants in a short time may be due to the mildness of locomotive disability among the participants. Our participants were community-dwelling elderly subjects, whereas the subjects in the JOA and JCOA reports were clinic patients [26, 27]. We may need to verify the possibility that the participants were healthy apart from their locomotive disability because the participants of this study were community-dwelling individuals who were recruited by open invitation. However, the data presented in Table 2 suggest that the participants were not particularly healthy with respect to their musculoskeletal conditions. The mean ages of the male and female participants of the current study were 74.1 and 71.6 years, respectively. In a study of a large-scale population-based cohort in Japan, Yoshimura et al. [4] found that the prevalences of KOA, LS, and lumbar OP in the group aged 70–79 years were 48.2, 85.3, and 3.6 %, respectively, among men and 71.9, 75.1, and 29.8 %, respectively, among women. Muraki et al. [30, 31] reported that, among the radiological osteoarthritis-affected subjects, one-fourth of the male participants and one-third of the female participants experienced pain. The national standard values (median) of PCS and MCS scores were 47.5 and 53.1, respectively, for men, and 47.3 and 53.6, respectively, for women (age range 70–75 years) [14]. Although careful judgment is required when comparing our data with those of previous studies, it may be safely said that our participants constituted a typical group for their age with respect to their mobility, rather than a particularly healthy volunteer group.

In conclusion, this study confirmed the safety of the exercise program we developed and indicated that the video exercise program provides greater motivation to participants than does the pamphlet exercise program. Moreover, this study demonstrated that our exercise program may improve low back pain and functional disability in participants. The single-leg standing and 6-m walking tests are possibly useful indices for evaluating the short-term effects of exercise on balance and mobility in the elderly. Although these results are preliminary, we believe that this study provides fundamental information for future studies.

Acknowledgments

This work was supported by the consigned research fund of Wakayama Prefecture Nos. B-21006 and B-22014. The authors thank Dr. Hiroaki Terashita of Mikimachi Terashita Orthopaedic Clinic for his precise advice in planning this study and Mr. Yoshihisa Kitaoka and other members of the public office in Hashimoto City for their assistance in selecting locations and scheduling participants for examinations.

Conflict of interest

The video exercise program in this study was developed with technical cooperation from Wakayama Telecasting Corp (WTV). WTV developed a commercial DVD video containing this exercise program under the editorial supervision of M.Y. and H.H. However, none of the authors received any benefits from the company.

References

1. Statistics Bureau. Current population estimates as of October 1, 2007. Available at: http://www.stat.go.jp/english/data/jinsui/2007np/index.htm. Accessed Mar 13, 2012.
2. Nakamura K. A “super-aged” society and the “locomotive syndrome”. J Orthop Sci. 2008;13:1–2.
3. Ministry of Health, Labour and Welfare. Comprehensive survey of living conditions. 14. Rate of Persons with subjective symptoms (per 1000 population) by type of symptoms, sex and age group (multiple answer), 2007. Available at: http://www.mhlw.go.jp/english/database/db-hss/cslc-tables.html. Accessed Mar 13, 2012.
4. Yoshimura N, Muraki S, Oka H, Mabuchi A, En-Yo Y, Yoshida M, et al. Prevalence of knee osteoarthritis, lumbar spondylosis, and osteoporosis in Japanese men and women: the research on osteoarthritis/osteoporosis against disability study. J Bone Miner Metab. 2009;27:620–8.
5. Nakamura K. Locomotive syndrome: disability-free life expectancy and locomotive organ health in a “super-aged” society. J Orthop Sci. 2009;14:1–2.
6. Hayden JA, van Tulder MW, Malmivaara A, Koes BW. Exercise therapy for treatment of non-specific low back pain. Cochrane Database Syst Rev. 2005;3:CD000335.
7. Richmond J, Hunter D, Irrgang J, Jones MH, Levy B, Marx R, et al. Treatment of osteoarthritis of the knee (nonarthroplasty). J Am Acad Orthop Surg. 2009;17:591–600.
8. Borg GA. Psychophysical bases of perceived exertion. Med Sci Sports Exerc. 1982;14:377–81.
9. Kellgren JH, Lawrence JS. Radiological assessment of osteo-arthrosis. Ann Rheum Dis. 1957;16:494–502.
10. Orimo H, Hayashi Y, Fukunaga M, Sone T, Fujiwara S, Shiraki M, et al. Diagnostic criteria for primary osteoporosis: year 2000 revision. J Bone Miner Metab. 2001;19:331–7.
11. Fujiwara A, Kobayashi N, Saiki K, Kitagawa T, Tamai K, Saotome K. Association of the Japanese Orthopaedic Association score with the Oswestry Disability Index, Roland-Morris Disability Questionnaire, and short-form 36. Spine. 2003;28:1601–7.
12. Suzukamo Y, Fukuhara S, Kikuchi S, Konno S, Roland M, Iwamoto Y, et al. Validation of the Japanese version of the Roland-Morris Disability Questionnaire. J Orthop Sci. 2003;8:543–8.
13. Nakamura M, Miyamoto K, Shimizu K. Validation of the Japanese version of the Roland-Morris Disability Questionnaire for Japanese patients with lumbar spinal disorders. Spine. 2003;28:241–8.
14. Fukuhara S, Suzukamo Y. Manual of the SF-8 Japanese version: Institute for Health Outcomes and Process Evaluation Research, Kyoto, 2004 (in Japanese).
15. Seichi A, Hoshino Y, Doi T, Akai M, Tobimatsu Y, Iwaya T. Development of a screening tool for risk of locomotive syndrome in the elderly: the 25-question Geriatric Locomotive Function Scale. J Orthop Sci. 2012;17:163–72.

16. Roddy E, Zhang W, Doherty M. Aerobic walking or strengthening exercise for osteoarthritis of the knee? A systematic review. Ann Rheum Dis. 2005;64:544–8.
17. Rainville J, Hartigan C, Martinez E, Limke J, Jouve C, Finno M. Exercise as a treatment for chronic low back pain. Spine J. 2004;4:106–15.
18. Vestergaard S, Kronborg C, Puggaard L. Home-based video exercise intervention for community-dwelling frail older women: a randomized controlled trial. Aging Clin Exp Res. 2008;20:479–86.
19. Haines TP, Russell T, Brauer SG, Erwin S, Lane P, Urry S, et al. Effectiveness of a video-based exercise programme to reduce falls and improve health-related quality of life among older adults discharged from hospital: a pilot randomized controlled trial. Clin Rehabil. 2009;23:973–85.
20. Reo JA, Mercer VS. Effects of live, videotaped, or written instruction on learning an upper-extremity exercise program. Phys Ther. 2004;84:622–33.
21. Phelan EA, Deyo RA, Cherkin DC, Weinstein JN, Ciol MA, Kreuter W, et al. Helping patients decide about back surgery: a randomized trial of an interactive video program. Spine. 2001;26:206–11.
22. Lin PC, Lin LC, Lin JJ. Comparing the effectiveness of different educational programs for patients with total knee arthroplasty. Orthop Nurs. 1997;16:43–9.
23. van Iersel MB, Munneke M, Esselink RA, Benraad CE, Olde Rikkert MG. Gait velocity and the Timed-Up-and-Go test were sensitive to changes in mobility in frail elderly patients. J Clin Epidemiol. 2008;61:186–91.
24. Shinkai S, Watanabe S, Kumagai S, Fujiwara Y, Amano H, Yoshida H, et al. Walking speed as a good predictor for the onset of functional dependence in a Japanese rural community population. Age Ageing. 2000;29:441–6.
25. Guralnik JM, Ferrucci L, Simonsick EM, Salive ME, Wallace RB. Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. N Engl J Med. 1995;332:556–61.
26. Sakamoto K, Nakamura T, Hagino H, Endo N, Mori S, Muto Y, et al. Effects of unipedal standing balance exercise on the prevention of falls and hip fracture among clinically defined high-risk elderly individuals: a randomized controlled trial. J Orthop Sci. 2006;11:467–72.
27. Kita K, Hujino K, Nasu T, Kawahara K, Sunami Y, Japanese Clinical Orthopaedic Association, Committee on Musculoskeletal Rehabilitation. A simple protocol for preventing falls and fractures in elderly individuals with musculoskeletal disease. Osteoporos Int. 2007;18:611–9.
28. Sherrington C, Whitney JC, Lord SR, Herbert RD, Cumming RG, Close JC. Effective exercise for the prevention of falls: a systematic review and meta-analysis. J Am Geriatr Soc. 2008;56:2234–43.
29. Howe TE, Rochester L, Neil F, Skelton DA, Ballinger C. Exercise for improving balance in older people. Cochrane Database Syst Rev. 2011;11:CD004963.
30. Muraki S, Oka H, Akune T, Mabuchi A, En-Yo Y, Yoshida M, et al. Prevalence of radiographic lumbar spondylosis and its association with low back pain in elderly subjects of population-based cohorts: the ROAD study. Ann Rheum Dis. 2009;68:1401–6.
31. Muraki S, Oka H, Akune T, Mabuchi A, En-yo Y, Yoshida M, et al. Prevalence of radiographic knee osteoarthritis and its association with knee pain in the elderly of Japanese population-based cohorts: the ROAD study. Osteoarthr Cartil. 2009;17:1137–43.

Osteoporos Int (2014) 25:1089–1098
DOI 10.1007/s00198-013-2489-0

ORIGINAL ARTICLE

Prevalence and progression of radiographic ossification of the posterior longitudinal ligament and associated factors in the Japanese population: a 3-year follow-up of the ROAD study

N. Yoshimura · K. Nagata · S. Muraki · H. Oka · M. Yoshida · Y. Enyo · R. Kagotani · H. Hashizume · H. Yamada · Y. Ishimoto · M. Teraguchi · S. Tanaka · H. Kawaguchi · Y. Toyama · K. Nakamura · T. Akune

Received: 14 May 2013 / Accepted: 5 August 2013 / Published online: 22 August 2013

Abstract
Summary The prevalence of radiographic cervical ossification of the posterior longitudinal ligament (OPLL) in 1,562 Japanese from a population-based cohort was 1.9 %. The presence of OPLL showed a significant association with the femoral neck bone mineral density (BMD), presence of diffuse idiopathic skeletal hyperostosis (DISH) and plasma pentosidine levels. Only one new case of radiographic OPLL was detected, but OPLL progressed in all affected subjects.
Introduction The purpose of this study was to clarify the prevalence and progression of radiographic OPLL and the associated factors, using the population-based cohort Research on Osteoarthritis/osteoporosis Against Disability (ROAD).
Methods In the ROAD study, 1,690 participants underwent X-ray examination of the entire spine and both knees. Radiographic OPLL, lumbar spondylosis, knee osteoarthritis and DISH were diagnosed by a single, well-experienced orthopaedic surgeon. An interviewer-administered questionnaire and tests for anthropometric measurements were administered, and the BMDs of the lumbar spine and proximal femur were determined. A new OPLL case was considered if heterotopic ossification in the posterior longitudinal ligament was absent at baseline but present during follow-up. Progression was defined as an increase in the maximum length or width of the ossification at follow-up over that at baseline.
Results Radiographic OPLL was detected in 30 (17 men, 13 women) of 1,562 individuals who underwent X-ray examination of the cervical spine (prevalence=1.9 %). Its prevalence was significantly higher in men than in women (p=0.007), but no association with age was observed. In a logistic regression analysis, OPLL showed a significant association with the femoral neck BMD, presence of DISH and plasma pentosidine levels. Only one new case of radiographic OPLL was detected, but OPLL progressed in all affected subjects.
Conclusion This population-based study clarified the prevalence of radiographic OPLL in the Japanese population as well as its progression. OPLL showed significant association with plasma pentosidine levels, BMD and DISH.

Keywords Bone mineral density · Diffuse idiopathic skeletal hyperostosis · Ossification of posterior longitudinal ligament of cervical spine · Plasma pentosidine · Prevalence · Progression

Electronic supplementary material The online version of this article (doi:10.1007/s00198-013-2489-0) contains supplementary material, which is available to authorized users.

N. Yoshimura (✉) · H. Oka
Department of Joint Disease Research, 22nd Century Medical and Research Center, Graduate School of Medicine, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8655, Japan
e-mail: YOSHIMURAN-ORT@h.u-tokyo.ac.jp

K. Nagata · M. Yoshida · Y. Enyo · R. Kagotani · H. Hashizume · H. Yamada · Y. Ishimoto · M. Teraguchi
Department of Orthopedic Surgery, Wakayama Medical University, 811-1 Kimidera, Wakayama, Wakayama 641-8509, Japan

S. Muraki · T. Akune
Department of Clinical Motor System Medicine, 22nd Century Medical and Research Center, Graduate School of Medicine, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8655, Japan

S. Tanaka · H. Kawaguchi
Department of Orthopaedic Surgery, Graduate School of Medicine, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8655, Japan

Y. Toyama
Department of Orthopaedic Surgery, School of Medicine, Keio University, 35 Shinanomachi, Shinjuku-ku, Tokyo 160-8582, Japan

K. Nakamura
National Rehabilitation Center for Persons with Disabilities, 1, Namiki 4-chome, Tokorozawa, Saitama 359-8555, Japan

Introduction

Ossification of the posterior longitudinal ligament of the spine (OPLL) is the pathological ectopic ossification of this ligament at the cervical and thoracic spine. It causes myeloradiculopathy as a result of chronic pressure on the spinal cord and nerve roots [1, 2]. Epidemiologic studies have shown a relatively high prevalence of OPLL among the Japanese, a slightly lower prevalence among East Asians and a substantially lower prevalence among whites [3, 4].

In terms of its characteristics, several epidemiological studies have reported that adult-onset obesity and diabetes mellitus (DM) are independent risk factors of OPLL [5, 6]. Further, OPLL often coincides with diffuse idiopathic skeletal hyperostosis (DISH), a systemic disorder of hyperossification. McAfee et al. [7] found that seven (50 %) of 14 patients with OPLL had DISH, and in a Japanese study, DISH was present in 27 (25 %) of 109 patients with OPLL [8].

Besides the coexistence of other disorders such as DM and DISH, little detailed information is available on the profile of OPLL in the general population. These data are important in order to characterise the disease burden. In addition, limited information is available regarding factors associated with OPLL, including biochemical markers of bone turnover, bone mineral density (BMD) values, lifestyle factors, or other coexisting disorders, such as dyslipidaemia, impairment of glucose tolerance, lumbar spondylosis (LS) and knee osteoarthritis (KOA).

Thus, the aims of the present study were to clarify the prevalence of OPLL in the Japanese population and to examine the association of OPLL with biological and environmental factors as well as coexisting disorders. For this, we used a questionnaire survey and the large, population-based cohort Research on Osteoarthritis/osteoporosis Against Disability (ROAD), which included lifestyle factors and nutrition, blood and urinary examinations, BMD measurements and X-ray examinations [9, 10].

Methods

Outline of the ROAD study

We conducted the present study using the cohorts established in 2005 for the ROAD study. The ROAD study is a nationwide, prospective study of OA comprising population-based cohorts from several communities in Japan. The details of the cohort profile have been reported elsewhere [9, 10]. Briefly, in 2005–2007, we created a baseline database that included clinical and genetic information for 3,040 residents of Japan (1,061 men, 1,979 women); the mean age (deviation [SD]) of the participants was 70.3 [11.0] years (71.0 [10.7] years for men and 69.9 [11.2] years for women). The subjects were recruited from resident registration listings in three communities with different characteristics: 1,350 subjects (465 men, 885 women) were from an urban region in Itabashi, Tokyo; 864 subjects (319 men, 545 women) were from a mountainous region in Hidakagawa, Wakayama and 826 subjects (277 men, 549 women) were from a coastal region in Taiji, Wakayama.

The participants completed an interviewer-administered questionnaire of 400 items that included lifestyle information such as occupation, smoking habits and alcohol consumption; family history; medical history; physical activity; reproductive variables and health-related quality of life. A questionnaire was prepared by modifying the one used in the Osteoporotic Fractures in Men Study [11], and some new items were added to the modified questionnaire. The participants were asked whether they took prescription medication daily or nearly every day (0 = no, 1 = yes). If participants did not know the reason for the prescribed medication, they were asked to bring their medications to the medical doctor (NY).

Anthropometric measurements included height (in centimetres), body weight (in kilograms), arm span (in centimetres), bilateral grip strength (in kilograms) and body mass index (BMI; in kilograms per square metre). Experienced orthopaedic surgeons collected medical information on systematic, local and mental status, including information on back, knee and hip pain; swelling and range of motion of the joints and patellar and Achilles tendon reflexes.

In 2008–2010, we attempted to locate and follow up all 3,040 subjects. They were invited for the second survey of the ROAD study, which included a 3-year follow-up of the same examinations as the baseline.

Subjects eligible for the present study

In the present study, we enrolled all 1,690 subjects (men, 596; women, 1,094) from mountainous and coastal areas who had enrolled in the ROAD study. In the ROAD study, X-ray examination of the cervical and thoracic spine had been performed only for these subjects and not for those from the urban region. Further, for all these 1,690 participants, the BMDs for the lumbar spine and the proximal femur had been measured using dual energy X-ray absorptiometry (Hologic Discovery; Hologic, Waltham, MA, USA) during the baseline examination. Additionally, blood and urinary examinations had also been performed for these subjects.

The study participants provided written informed consent, and the study was conducted with the approval of the ethics committees of the University of Tokyo (no. 1264 and no. 1326) and the University of Wakayama Medical University (no. 373).

Radiographic assessment

Plain radiographs were obtained for the cervical, thoracic and lumbar spine in the anteroposterior and lateral views and both knees in the anteroposterior view with weight-bearing and footmap positioning.

Cervical OPLL was diagnosed using plain radiographs of the cervical spine in the lateral view. OPLL was indicated by the presence of heterotopic ossification in the posterior longitudinal ligament on a lateral cervical radiograph. Radiographic OPLL was diagnosed by a single, experienced orthopaedic surgeon (KN) who was blinded to participants' clinical status. OPLL was classified into the following types: continuous, segmental and mixed. In the original OPLL classification by Tsuyama [3], it was categorised into four modes, namely continuous, segmental, mixed and localised. However, here, because of the small number of subjects in the localised category, these subjects were included in the continuous category. If OPLL was observed, the maximum length (continuous and localised type, upper limit to lower limit; segmental and mixed types, upper limit to lower limit of the longest serial region) and width of ossification were measured using the imaging software OsiriX (http://www.osirix-viewer.com/).

In addition, using radiographs of spine and knees, we determined the grade of OA. The severity of radiographic OA was determined according to the Kellgren–Lawrence (KL) grading [12] as follows: KL0, normal; KL1, slight osteophytes; KL2, definite osteophytes; KL3, joint or intervertebral space narrowing with large osteophytes and KL4, bone sclerosis, joint or intervertebral space narrowing and large osteophytes. Radiographs for each site, i.e. the vertebrae and knees, were examined by a single, experienced orthopaedic surgeon (SM) who was blinded to participants' clinical status. In the present study, the subject's KL grade was considered the maximum grade diagnosed for at least one intervertebral level of the lumbar spine or at least one knee joint.

We also investigated the presence of DISH using whole-spine X-ray films. The criterion for the definite diagnosis of DISH was the presence of four or more vertebral bodies with contiguous ligamentous ossification and calcification, which is known as Resnick and Niwayama's criterion [13]. DISH was diagnosed by a single, experienced orthopaedic surgeon (RK) who was blinded to participants' clinical status.

Blood and urine examinations

Samples were collected from the end of October to the middle of January from both mountainous and coastal areas. All blood and urine samples were extracted between 0900 and 1500 hours. The blood samples were centrifuged, and the sera and urine samples were immediately placed on dry ice and transferred to a deep freezer within 24 h. The samples were stored at −80 °C until assayed.

The blood samples were used to measure haemoglobin A1c (HbA1c, Japan Diabetes Society), serum levels of total cholesterol, uric acid and creatinine levels. The analyses were performed at the same laboratory within 24 h of collection (Osaka Kessei Research Laboratories, Inc., Osaka, Japan).

Serum levels of intact parathyroid hormone (iPTH) were measured using an electrochemiluminescence immunoassay (Roche Diagnostics GmbH, Mannheim, Germany). As a marker of bone formation, serum levels of N-terminal propeptide of type I procollagen (PINP) were measured using a radioimmunoassay (Orion Diagnostics, Espoo, Finland). The urinary levels of β-isomerised C-terminal cross-linking telopeptide of type I collagen (β-CTX), a bone resorption marker, were determined using an enzyme-linked immunosorbent assay (Fujirebio, Inc., Tokyo, Japan). Urinary β-CTX values were standardised to urinary creatinine concentrations. Plasma pentosidine levels were detected using a competitive ELISA kit (FSK pentosidine ELISA kit; Fushimi Pharmaceutical, Kagawa, Japan) as previously described [14].

Three-year follow-up and definition of OPLL occurrence and progression

In 2008–2010, the 1,690 subjects were invited to enrol in the second survey of the ROAD study, a 3-year follow-up consisting of examinations identical to those conducted at baseline. Spine and knee radiographs were also obtained at follow-up. All cervical radiographs were read by the same orthopaedic surgeon who read them at the baseline (KN), and he was again blinded to participants' clinical status. He simultaneously compared the X-ray films at the baseline and 3-year follow-up and thereby diagnosed OPLL. A new OPLL case was diagnosed if heterotopic ossification in the posterior longitudinal ligament was absent on the lateral cervical radiograph obtained at baseline but present in that obtained during follow-up. OPLL progression was defined as an increase in the maximum length or width of the heterotopic ossification during follow-up compared to that at baseline.

Statistical analysis

All statistical analyses were performed using STATA statistical software (STATA Corp., College Station, TX, USA). Differences in proportions were compared using the chi-square test. Differences in continuous variables were tested for significance using analysis of variance for multiple groups or Scheffe's least significant difference test for pairs of groups. All p values and 95 % confidence intervals (CI) are two sided.

To test the association between OPLL and potential risk factors, we used logistic regression analysis with the presence or absence of OPLL (0 = absence, 1 = presence) as an objective variable and select potential explanatory variables, in addition to basic characteristics such as age (+1 year), gender (0 = men, 1 = women) and regional differences (0 = mountainous area, 1 = coastal area). The selected associated factors were those that showed a significant ($p<0.05$) association with OPLL status in a simple linear analysis. To test the association between OPLL progression and associated factors, we used multivariate regression analysis with the change rate (percent per year) of the maximum length or width as an objective variable and the explanatory variables used in the above-mentioned logistic regression analysis. The explanatory variables in the logistic regression analysis and multivariate regression analysis are described in the "Results" section.

Results

Prevalence of radiographic OPLL

The X-ray radiographs of 1,562 of the 1,690 subjects (92.4 %, 520 men, 1,038 women) showed all parts of the lateral cervical spine, from C1 to C7. Among these 1,562 individuals, 30 (17 men, 13 women) were diagnosed with radiographic OPLL; thus, the prevalence of OPLL was estimated at 1.9 % (men, 3.2 %; women, 1.3 %), and it was significantly higher in men than in women ($p = 0.007$).

Figure 1 shows the prevalence of OPLL classified by age and gender. The prevalence of OPLL was not associated with age in either men or women.

In the 30 subjects with radiographic OPLL, the OPLL was categorised into the continuous type in 13 subjects (six men and seven women, 43.3 %), the segmented type in eight (six men and two women, 26.7 %), the mixed type in seven (four men and three women, 23.3 %) and the localised type in two (one man and one woman, 6.7 %). The largest OPLL region was most commonly observed in C4 (ten individuals; 33.3 %; three men and seven women), followed by C5 (nine individuals; 33.0 %; eight men and one woman), C3 (seven individuals; 23.3 %; four men and three women), C6 (three individuals; 10.0 %; two men and one women) and C2 (one individual; 3.3 %; one woman). The largest OPLL region was not found in C1 or C7 in any subject.

The mean length and width (standard deviation, SD) of the largest region of ossification at the baseline were 27.6 (16.0) and 3.0 (1.5) mm, respectively. The values in men were 26.1 (14.5) and 2.9 (1.4) mm, and those in women were 29.6 (18.1) and 3.2 (1.5) mm, respectively; thus, no significant difference was observed between men and women in this regard.

Factors associated with OPLL

Table 1 shows the baseline characteristics of 1,562 participants with and without OPLL. Overall, subjects with OPLL tended to be taller and heavier than those without OPLL ($p < 0.05$). Further, compared to individuals without OPLL, those with OPLL had higher plasma pentosidine levels and higher BMD values for both the lumbar spine (L2–4) and femoral neck ($p < 0.05$).

Table 1 also shows the prevalence of LS, KOA and DISH on the basis of OPLL status. The prevalence of LS with ≥grade 2 KL and that of DISH was higher in the group with OPLL than in the one without OPLL ($p < 0.05$), although no significant association was observed between the prevalence of KOA and the presence of OPLL.

Logistic regression analysis was performed with the OPLL status as the objective variable (0 = absence, 1 = presence). As explanatory variables, the analysis involved select associated factors that showed a significant ($p < 0.05$) association with OPLL status in the simple linear analysis, namely, height (in centimetres), weight (in kilograms), values of plasma pentosidine (+1 μg/mL), BMD of the femoral neck (+1 SD), presence of LS based on KL grade (0 = KL grade 0 or 1, 1 = KL grade≥2) and DISH (0 = absent, 1 = present), after adjustments were made for age (years) and gender (0 = men, 1 = women). As seen from Table 2, plasma pentosidine levels, BMD of the femoral neck and the presence of DISH were found to be significant associated factors for the presence of OPLL (Table 2). Further, when BMD of the lumbar spine (L2–4) was used instead of that of the femoral neck, this factor was also found to be significantly associated with OPLL (+1 SD; odds ratio (OR), 1.52; 95 % CI, 1.05–2.20; $p = 0.026$), but the

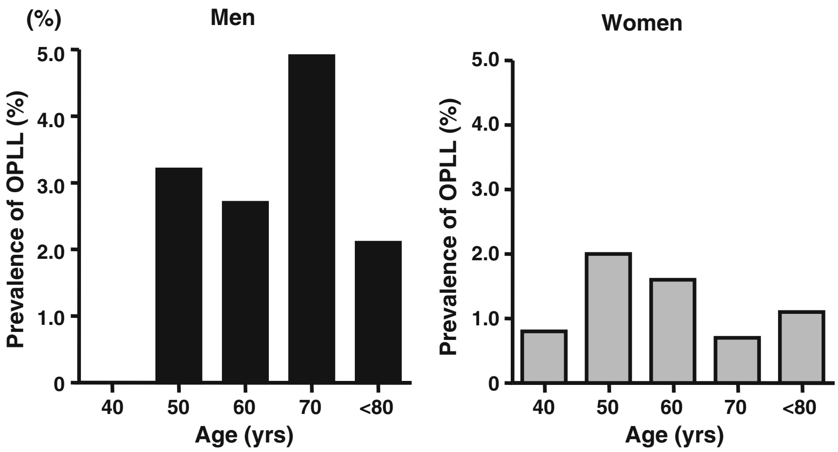

Fig. 1 Prevalence of OPLL classified by age and gender

Table 1 Baseline characteristics of participants classified by the presence or absence of OPLL

	Total (N=1,562)			Men (N=524)			Women (N=1,038)		
	OPLL (−) N=1,532	OPLL (+) N=30	p	OPLL (−) N=507	OPLL (+) N=17	p	OPLL (−) N=1,025	N=1,025 N=13	p
Age distribution (prevalence, %)									
30 years and younger	43	0 (0.0)		12	0 (0.0)		31	0 (0.0)	
40–49 years	141	1 (0.7)		39	0 (0.0)		102	1 (1.0)	
50–59 years	291	7 (2.4)	0.729	92	3 (3.2)	0.604	199	4 (2.0)	0.787
60–69 years	449	9 (2.0)		142	4 (2.7)		307	5 (1.6)	
70–79 years	468	11 (2.3)		175	9 (4.9)		293	2 (0.7)	
80 years and older	140	2 (1.4)		47	1 (2.1)		93	1 (1.1)	
Age (years), mean (SD)	62.9 (12.1)	67.0 (9.3)	0.3495	66.0 (11.7)	70.7 (8.0)	0.0990	64.4 (12.2)	62.2 (9.0)	0.5069
Height (cm), mean (SD)	154.9 (9.1)	159.1 (7.5)	0.0132*	163.3 (7.0)	163.9(5.4)	0.7414	150.8 (6.9)	152.8 (4.6)	0.2945
Weight (kg), mean (SD)	55.0 (10.3)	60.3 (10.1)	0.0053**	61.6 (10.5)	62.7 (8.2)	0.6759	51.7 (8.5)	57.1 (11.7)	0.0219*
BMI (kg/m^2), mean (SD)	22.8 (3.2)	23.8 (3.4)	0.1135	23.0 (3.1)	23.3 (2.1)	0.7434	22.7 (3.3)	24.4 (4.6)	0.0671
Residing in the coastal area (%)	49.4	53.3	0.671	46.4	58.8	0.311	50.9	46.2	0.732
Current smoking habit (regularly, ≥1/month) (%)	12.9	23.3	0.095	31.1	41.2	0.377	3.8	0.0	0.472
Current alcohol consumption (regularly, ≥1/month) (%)	39.1	43.3	0.637	66.1	64.7	0.907	25.8	15.4	0.395
Total cholesterol (mg/dL), mean (SD)	208.8 (34.5)	209.6 (36.2)	0.8954	198.6 (34.1)	204.4 (33.5)	0.4874	213.8 (33.6)	216.4 (39.8)	0.7840
Uric acid (mg/dL), mean (SD)	4.84 (1.30)	5.24 (1.21)	0.0943	5.71 (1.26)	5.71 (1.03)	0.9867	4.42 (1.09)	4.65 (1.21)	0.4528
HbA1c (Japan Diabetes Society) (%), mean (SD)	5.17 (0.70)	5.38 (0.79)	0.1124	5.20 (0.79)	5.44 (0.95)	0.2162	5.16 (0.64)	5.29 (0.56)	0.4595
Serum levels of iPTH (pg/mL), mean (SD)	41.2 (34.4)	41.2 (14.2)	0.9952	42.6 (54.4)	41.1 (13.9)	0.9083	40.5 (17.4)	41.3 (15.1)	0.8748
Serum levels of PINP (μg/L), mean (SD)	57.9 (27.0)	52.6 (29.9)	0.2915	47.5 (22.0)	42.6 (14.9)	0.3619	63.1 (27.8)	65.8 (39.2)	0.7301
Urinary levels of β-CTX (μg/mmol Cr), mean (SD)	187.2 (121.3)	150.4 (79.1)	0.0985	128.4 (78.7)	119.8 (58.3)	0.6529	216.2 (128.0)	190.5 (86.8)	0.4693
Plasma levels of pentosidine (μg/mL), mean (SD)	0.058 (0.037)	0.085 (0.140)	0.0005***	0.061 (0.048)	0.102 (0.184)	0.0042**	0.057 (0.030)	0.062 (0.037)	0.5012
BMD of the lumbar spine L2-4 (g/cm^2), mean (SD)	0.925 (0.205)	1.084 (0.205)	<0.0001***	1.038 (0.203)	1.176 (0.176)	0.0058**	0.868 (0.181)	0.965 (0.181)	0.0575
BMD of the femoral neck (g/cm^2), mean (SD)	0.667 (0.137)	0.747 (0.134)	0.0016**	0.739 (0.132)	0.797 (0.110)	0.0727	0.631 (0.124)	0.681 (0.139)	0.1558
Presence of LS (KL grade≥2) (%)	61.8	83.3	0.016*	76.1	100.0	0.022*	54.7	61.5	0.624
Presence of KOA (KL grade≥2) (%)	49.5	56.7	0.440	41.4	41.2	0.986	53.6	76.9	0.093
Presence of DISH (%)	9.4	33.3	<0.001***	0.7	52.9	0.002**	3.8	7.7	0.469

OPLL ossification of posterior longitudinal ligament, *SD* standard deviation, *BMI* body mass index, *HbA1c* haemoglobin A1c, *iPTH* intact parathyroid hormone, *PINP* N-terminal propeptide of type I procollagen, *β-CTX* β-isomerised C-terminal cross-linking telopeptide of type I collagen, *BMD* bone mineral density, *LS* lumbar spondylosis, *KOA* knee osteoarthritis, *KL grade* Kellgren–Lawrence grade, *DISH* diffuse idiopathic skeletal hyperostosis, *OPLL(−)* absence of OPLL, *OPLL(+)* presence of OPLL

*$p<0.05$; **$p<0.01$; ***$p<0.001$

Table 2 Odds ratios of potential factors associated with the presence of OPLL vs. the absence of OPLL

Explanatory variables	Reference	OR	95 % CI	*p*
Age (years)	+1 year	1.03	0.98–1.07	0.269
Gender	0 = men, 1 = women	1.30	0.39–4.34	0.666
Height (cm)	+1 cm	1.04	0.96–1.12	0.352
Weight (kg)	+1 kg	1.00	0.96–1.05	0.909
Pentosidine (μg/mL)	+0.01 μg/mL	1.05	1.00–1.09	0.038*
BMD (femoral neck) (g/cm2)	+1 SD	1.55	1.04–2.33	0.033*
Presence of LS (KL grade≥2)	0 = no, 1 = yes	1.94	0.67–5.61	0.219
Presence of DISH	0 = no, 1 = yes	2.78	1.11–6.92	0.029*

Logistic regression analysis was performed using the status of OPLL as the objective variable (0 = absence, 1 = presence), and the abovementioned factors were correspondingly adjusted

OPLL ossification of posterior longitudinal ligament, *BMD* bone mineral density, *LS* lumbar spondylosis, *KL grade* Kellgren–Lawrence grade, *DISH* diffuse idiopathic skeletal hyperostosis, *SD* standard deviation, *OR* odds ratios, *95 % CI* 95 % confidence interval

***p**<0.05; ***p*<0.01; ****p*<0.001

association of plasma pentosidine levels and DISH weakened (plasma pentosidine +0.01 μg/mL, 1.04, 0.997–1.087, $p=0.069$; presence of DISH 2.37, 0.94–6.00, $p=0.069$).

New occurrence or progression of OPLL

During the three study years, 1,380 individuals (88.3 %; 466 men, 914 women) among the 1,562 subjects at baseline returned for follow-up, and their radiographs were available for observation. Among the 30 individuals with radiographic cervical OPLL at baseline, 25 (83.3 %; 14 men and 11 women) participated in the second survey.

The remaining 1,355 individuals who did not have cervical OPLL at baseline and who participated in the initial and second surveys were regarded as members of the population at risk for the occurrence of OPLL. Among them, only one woman was diagnosed with newly developed radiographic OPLL (incidence 2.46/10,000 per year).

At follow-up, the mean length (in millimetres, SD) and width (in millimetres, SD) of the maximum region of ossification among the 25 individuals with OPLL was 28.7 (16.1) and 3.5 (1.5) mm, respectively. Since the mean values of length and width of the maximum region of ossification of these 25 subjects were 27.0 (16.2) and 3.0 (1.5) mm at the baseline, respectively, both the length and width of the maximum region of ossification increased, although a significant difference was not observed.

To clarify the risk factors associated with this increase in the length and width of the ossification, we performed multivariate regression analysis using the rate of change in these parameters as objective variables and the explanatory variables as those used in the logistic regression analysis, namely height (in centimetres), weight (in kilograms), plasma pentosidine levels (+1 μg/mL), BMD of the femoral neck (+1 SD), presence of LS based on the KL grade (0 = KL grade 0 or 1, 1 = KL grade≥2) and DISH (0 = absence, 1 = presence). Adjustments for age (years) and gender (0 = men, 1 = women) were made. However, none of the abovementioned variables was found to be significantly associated with the rate of changes in the length or width.

Discussion

In the present population-based study, we clarified the prevalence of radiographic OPLL in the general Japanese population, and we found that it is significantly associated with high plasma pentosidine levels, high BMD and the presence of DISH. The 3-year follow-up study also showed that new cases were very rare, and the length and width of the maximum region of ossification among the subjects with OPLL tended to increase.

The prevalence of OPLL in Japan has been reported to be 1.9 to 4.3 % among individuals aged 30 years and older [1, 15–17]. In other Asian countries, such as in Korea [18, 19] and Taiwan [20], a similar prevalence was reported, but it was lower in Western countries [21], suggesting that ethnic and/or genetic factor(s) could be associated with the onset of OPLL. In the present study, the prevalence of OPLL was found to be 1.9 %. This is consistent with the value found in previous reports. However, it is difficult to clearly distinguish localised-type OPLL from osteophytic changes, and we included two individuals with localised-type OPLL in the OPLL group. Thus, we may have overestimated the presence of radiographic OPLL. If we exclude individuals with localised-type OPLL from the OPLL group, the prevalence of the OPLL in the present study is 1.8 %.

With regard to the gender difference in OPLL prevalence, the prevalence was previously reported to be three times higher in men than in women [22]. We found that men are 2.5 times more likely to have OPLL than women (men 3.2 %, women

1.3 %), which is consistent with results reported previously among Japanese subjects. In contrast, symptomatic OPLL was reported to be usually observed in the sixth decade of life [22], although we were unable to find a significant association between age and the presence of OPLL. This might be explained by the fact that previous studies on the characteristics of OPLL were performed on the subjects with symptomatic OPLL, i.e. they had been clinically diagnosed with OPLL, while our subjects had radiographic OPLL that had not been clinically diagnosed. If the OPLL in our subjects progresses in the future, the peak age at which the symptoms could be expressed may be their 60s.

With regard to the comorbidities of OPLL, several reports have indicated that obesity and DM might be associated with OPLL [5, 6]. In the present study, the values of BMI tended to be higher in the group with OPLL than in that without OPLL, although this difference was not significant. A similar pattern was found in the values of HbA1c, and this finding could be explained by previous findings that the extent of ossification was significantly associated with the fasting serum insulin level but not with the fasting glucose level or the HbA1c level [23]. However, in the ROAD study, since all subjects could not be requested to fast, we could not confirm the association between fasting serum insulin levels and OPLL.

With regard to the association between biochemical markers of bone turnover and OPLL, Matsui et al. showed that the levels of the bone markers serum procollagen type I carboxyl-terminal peptide and intact osteocalcin were higher in patients with OPLL than in normal subjects [24]. This suggested that OPLL was associated with biochemical markers of bone turnover. In the present study, to evaluate the role of bone metabolism in OPLL, we compared the serum levels of iPTH and PINP as bone formation markers and the urinary levels of β-CTX between the groups with and without OPLL. However, we could not find significant differences between the groups.

Instead, the plasma pentosidine levels of the OPLL group were found to be significantly higher than those of the group without OPLL. This tendency remained after potential associated factors were adjusted for. Pentosidine is an advanced glycation end product, products generated by the sequential nonenzymatic glycosylation of protein amino groups [25] that accumulate in various tissues including kidney and coronary arteries, resulting in the development of diabetic vascular complications [26]. The concentrations of pentosidine in cortical and trabecular bone are reported to be adversely associated with bone strength [27–29]. Yamamoto et al. [30] found that serum pentosidine levels were positively associated with the presence of vertebral fractures in postmenopausal women with type 2 diabetes. Renal insufficiency was reported to be a dominant determinant of serum pentosidine levels [31] because of which serum pentosidine levels are increased in patients with chronic renal failure [32, 33]. However, no report has shown the association between pentosidine levels and the presence of OPLL. On the basis of the abovementioned reports, we performed multivariate logistic regression analysis using the same explanatory factors we had used in the analysis shown in Table 2, along with the estimated glomerular filtration rate. We found that the plasma pentosidine levels were still significantly related to the presence of OPLL (OR, 1.05; 95 % CI, 1.00–1.09; $p=0.042$). We speculate that the levels of pentosidine might be associated with ectopic ossification, such as vascular calcification in patients with renal dysfunction, or the presence of OPLL, directly or indirectly, although the currently available information is inadequate to prove this hypothesis. One reason for the inadequacy of the information obtained in this study could be that we did not evaluate genetic factors in the present study. Further investigations are needed to clarify whether the observed relationship between pentosidine levels and OPLL remains after analysis of other possible confounders, including genetic factors.

In addition to the biochemical markers, high BMDs have been observed in patients with OPLL [24, 34, 35]. However, Morio et al. reported that the BMD was lower in patients with advanced OPLL [36], suggesting that the disuse atrophy may result during advanced-stage OPLL. Our results also showed that subjects with OPLL had higher BMDs. However, the subjects in the present study all had radiographically determined OPLL but few clinical symptoms, so their condition may not have been in the advanced stage. Therefore, based solely on the results of the present study, we were unable to discuss the association between BMD and advanced-stage OPLL.

Several reports have shown that the coexistence of OPLL and DISH is quite common [4, 7, 8]. The pathogenesis of DISH and OPLL has been speculated to be similar, although the details remain unclear. For example, Havelka et al. analysed intron 6 (−4) polymorphisms in the COL 11 A2 gene in Czech patients with DISH and Japanese patients with OPLL, but they found no agreement between the data of subjects with DISH and OPLL [37]. Additional studies with a broader spectrum of genotyping and a larger cohort of patients may clarify the presence or absence of genetic relations between DISH and OPLL.

Few studies have been reported regarding the incidence of OPLL in the general population because OPLL is relatively rare and based on ethnicity, as noted. Using data collected in a pilot study in the corporation of 360 Japanese hospitals [3], Tsuyama described the incidence of OPLL and found that 2,142 patients were treated in these hospitals and the estimated incidence of OPLL was 19 patients per million persons of the total population [3]. In the present study, only one new case of OPLL was detected, so we could not accurately estimate the incidence of OPLL and compare our results to those of previous reports. In order to confirm the incidence of OPLL, we need to follow this cohort for a longer time.

Several studies have investigated the course of OPLL. Chiba et al. use computer-assisted measurement to examine OPLL progression, and they found that the rate of OPLL progression was 56.5 % over 2 years, and this rate was most common in younger patients with continuous- and mixed-type OPLL [38]. Murakami et al. followed the case of a 67-year-old man who had had cervical OPLL for more than 26 years, and they found that the rate of OPLL progression was 2.2, 8.8 and 2.0 mm/year from 1–4, 4–8 and 8–10 years after the first visit, respectively [39]. However, to our knowledge, no study has reported the progression of radiographically defined OPLL in the general population. In the present study, we found that both the length and width of the maximum region of ossification increased during the 3 years of the study, although it was not a significant change. A previous report [39] found no evidence of OPLL progression after 10 years. We must carefully examine whether or not radiographically defined OPLL progresses to clinical OPLL.

This study has several limitations. First, although the ROAD study includes a large number of participants, these participants may not truly be representative of the general population. To address this, we compared the anthropometric measurements and the frequencies of smoking and alcohol consumption between the study participants and the general Japanese population. No significant differences were found, with the exception that male ROAD study participants aged 70–74 years were significantly smaller in terms of body structure than men from the overall Japanese population ($p < 0.05$) [10]. This difference should be considered when evaluating potential risk factors for men aged 70–74 years; factors such as body build, particularly weight, are known to be associated with metabolic risk factors and KOA. Therefore, our results may have underestimated the prevalence of these conditions. Second, the total number of subjects with confirmed OPLL was very small, which might make the results somewhat less credible. In the present study, we used logistic regression analysis to adjust for gender differences. When the total number of the objective variable, namely OPLL cases, is small, using the multivariate model to adjust for gender differences may be more useful than using a gender-specific analysis. This is because the total number of cases in a gender-specific analysis will be even smaller, which reduces the statistical power. Although the significant associations between OPLL and the plasma levels of pentosidine and between OPLL and DISH were observed only in men in the simple comparative analysis, the pentosidine levels and DISH remained significant factors associated with the presence of OPLL even in the logistic regression analysis with adjustments for gender. We interpreted this result to mean that the female sex might dilute the strength of the association between OPLL and DISH, but the tendency in both genders remained significant.

To clarify the effect of sex differences in the interaction among OPLL, pentosidine levels and DISH, the logistic regression analysis was performed in men and women separately (Supplementary Table 1). In this logistic regression analysis, the presence of OPLL was significantly associated with the pentosidine levels and femoral neck BMD in men, but the association of OPLL with the presence of DISH was diluted to a marginal association ($p = 0.080$). Further, since all male patients with DISH had radiographic LS, we could not evaluate the association between OPLL and LS. In women, the associations among OPLL, pentosidine levels and DISH were not significant. Although these results may indicate that the significant associated factors were observed only in men, they may even be skewed by the small number of female cases. Under these circumstances, it is difficult to distinguish which model should be used, i.e. logistic regression analysis or the multivariate model. It may be necessary to first include an adequate number of OPLL cases before this can be decided. To compensate for these limitations, we decided to include the urban cohort of the ROAD study in the OPLL survey. Thus, more participants will be included in the third ROAD survey planned from 2012 to 2013, and further detailed investigation regarding the risk factors for the presence, occurrence or exacerbation of OPLL may be possible.

In summary, the present study clarified that the prevalence of radiographic cervical OPLL in 1,562 individuals was 1.9 %, which was significantly higher in men than in women ($p = 0.007$), but no association with age was observed. In logistic regression analysis, OPLL showed a significant association with the femoral neck BMD, presence of DISH and plasma pentosidine levels. Only one new case of radiographic OPLL was detected, but OPLL progressed in all affected subjects.

Acknowledgments This work was supported by Grants-in-Aid for Scientific Research B23390172 and B20390182 to NY, C20591737 to TA and C20591774 to SM; grants for Young Scientists A18689031 to HO; Collaborating Research with NSF 08033011-00262 (Director, NY) from the Ministry of Education, Culture, Sports, Science and Technology and H17-Men-eki-009 (Director, KN), H18-Choujyu-037 (Director, TN), H20-Choujyu-009 (Director, NY), H23-Choujyu-002 (Director, TA), H23-Nanchi-Ippan-032 (Director, YT) and H25-Choujyu-007 (Director, NY) from the Ministry of Health, Labour and Welfare in Japan. This study was also supported by grants from the Japan Osteoporosis Society (NY, SM, HO and TA) and research aid from the Japanese Orthopaedic Association (JOA-Subsidized Science Project Research 2006-1 and 2010-2, Director, HK). The authors wish to thank Dr. Takako Nojiri and Mr. Kazuhiro Hatanaka from the Gobo Public Health Centre; Dr. Naoki Hirabayashi of the Kawakami Clinic, Hidakagawa Town; Mrs. Tomoko Takijiri, Mrs. Kumiko Shinou, Mrs. Rie Takiguchi, Mrs. Kyoko Maeda, Ms. Ikuyo Ueyama, Mrs. Michiko Mori, Mrs. Hisayo Sugimoto and other members of the public office in Hidakagawa Town; Dr. Shinji Matsuda of the Shingu Public Health Centre and Mrs. Tamako Tsutsumi, Mrs. Kanami Maeda, Mr. Shoichi Shimoichi, Mrs. Megumi Takino, Mrs. Shuko Okada, Mrs. Kazuyo Setoh, Mrs. Chise Ryouno, Mrs. Miki Shimosaki, Mrs. Chika Yamaguchi, Mrs. Yuki Shimoji and other members of the public office in Taiji Town for their assistance in locating and scheduling participants for examinations. We also thank Ms. Kyoko Yoshimura, Mrs. Toki Sakurai and Mrs. Saeko Sahara for their assistance with data reduction and administration.

Conflicts of interest None.

References

1. Sakou T, Matsunaga S, Koga H (2000) Recent progress in the study of pathogenesis of ossification of the posterior longitudinal ligament. J Orthop Sci 5:310–315
2. Schmidt MH, Quinones-Hinojosa A, Rosenberg WS (2002) Cervical myelopathy associated with degenerative spine disease and ossification of the posterior longitudinal ligament. Semin Neurol 22:143–148
3. Tsuyama N (1984) Ossification of the posterior longitudinal ligament of the spine. Clin Orthop Relat Res 184:71–84
4. Inamasu J, Guiot BH, Sachs DC (2006) Ossification of the posterior longitudinal ligament: an update on its biology, epidemiology, and natural history. Neurosurgery 58:1027–1039
5. Kobashi G, Washio M, Okamoto K, Sasaki S, Yokoyama T, Miyake Y, Sakamoto N, Ohta K, Inaba Y, Tanaka H, Japan Collaborative Epidemiological Study Group for Evaluation of Ossification of the Posterior Longitudinal Ligament of the Spine Risk (2004) High body mass index after age 20 and diabetes mellitus are independent risk factors for ossification of the posterior longitudinal ligament of the spine in Japanese subjects: a case–control study in multiple hospitals. Spine 29:1006–1010
6. Shingyouchi Y, Nagahama A, Niida M (1996) Ligamentous ossification of the cervical spine in the late middle-aged Japanese men. Its relation to body mass index and glucose metabolism. Spine 21:2474–2478
7. McAfee PC, Regan JJ, Bohlman HH (1987) Cervical cord compression from ossification of the posterior longitudinal ligament in non-orientals. J Bone Joint Surg Br 69:569–575
8. Ehara S, Shimamura T, Nakamura R, Yamazaki K (1998) Paravertebral ligamentous ossification: DISH, OPLL and OLF. Eur J Radiol 27:196–205
9. Yoshimura N, Muraki S, Oka H, Kawaguchi H, Nakamura K, Akune T (2010) Cohort profile: Research on Osteoarthritis/Osteoporosis Against Disability (ROAD) study. Int J Epidemiol 39:988–995
10. Yoshimura N, Muraki S, Oka H, Mabuchi A, En-yo Y, Yoshida M, Saika A, Yoshida H, Suzuki T, Yamamoto S, Ishibashi H, Kawaguchi H, Nakamura K, Akune T (2009) Prevalence of knee osteoarthritis, lumbar spondylosis, and osteoporosis in Japanese men and women: the research on osteoarthritis/osteoporosis against disability study. J Bone Miner Metab 27:620–628. doi:10.1007/s00774-009-0080-8
11. Orwoll E, Blank JB, Barrett-Connor E, Cauley J, Cummings S, Ensrud K, Lewis C, Cawthon PM, Marcus R, Marshall LM, McGowan J, Phipps K, Sherman S, Stefanick ML, Stone K (2005) Design and baseline characteristics of the osteoporotic fractures in men (MrOS) study: a large observational study of the determinants of fracture in older men. Contemp Clin Trials 26:569–585
12. Kellgren JH, Lawrence LS (1957) Radiological assessment of osteoarthrosis. Ann Rheum Dis 16:494–502
13. Resnick D, Niwayama G (1976) Radiographic and pathologic features of spinal involvement in diffuse idiopathic skeletal hyperostosis (DISH). Radiology 119:559–568
14. Sanaka T, Funaki T, Tanaka T, Hoshi S, Niwayama J, Taitoh T, Nishimura H, Higuchi C (2002) Plasma pentosidine levels measured by a newly developed method using ELISA in patients with chronic renal failure. Nephron 91:64–73
15. Matsunaga S, Yamaguchi M, Hayashi K, Sakou T (1999) Genetic analysis of ossification of the posterior longitudinal ligament. Spine (Phila Pa 1976) 24:937–938
16. Okamoto K, Kobashi G, Washio M, Sasaki S, Yokoyama T, Miyake Y, Sakamoto N, Ohta K, Inaba Y, Tanaka H, Japan Collaborative Epidemiological Study Group for Evaluation of Ossification of the Posterior Longitudinal Ligament of the Spine (OPLL) Risk (2004) Dietary habits and risk of ossification of the posterior longitudinal ligaments of the spine (OPLL); findings from a case–control study in Japan. J Bone Miner Metab 22:612–617
17. Washio M, Kobashi G, Okamoto K, Sasaki S, Yokoyama T, Miyake Y, Sakamoto N, Ohta K, Inaba Y, Tanaka H, Japan Collaborative Epidemiological Study Group for Evaluation of Ossification of the Posterior Longitudinal Ligament of the Spine Risk (2004) Sleeping habit and other life styles in the prime of life and risk for ossification of the posterior longitudinal ligament of the spine (OPLL): a case–control study in Japan. J Epidemiol 14:168–173
18. Jin BH, Kim YS (1991) Ossification of spinal ligaments. J Korean Neurosurg Soc 20:875–884
19. Kim TJ, Bae KW, Uhm WS, Kim TH, Joo KB, Jun JB (2008) Prevalence of ossification of the posterior longitudinal ligament of the cervical spine. Joint Bone Spine 75:471–474, d
20. Wang PN, Chen SS, Liu HC, Fuh JL, Kuo BI, Wang SJ (1999) Ossification of the posterior longitudinal ligament of the spine. A case–control risk factor study. Spine (Phila Pa 1976) 24:142–145
21. Resnick D (1994) Diagnosis of bone and joint disorders. Saunders, London, pp 1496–1507
22. Otsuka K, Terayama K, Yanagihara M (1986) An epidemiological survey on ossification of ligaments in the cervical and thoracic spine in individuals over 50 years of age. J Jpn Orthop Assoc 60:1087–1098
23. Akune T, Ogata N, Seichi A, Ohnishi I, Nakamura K, Kawaguchi H (2001) Insulin secretory response is positively associated with the extent of ossification of the posterior longitudinal ligament of the spine. J Bone Joint Surg Am 183A:1537–1544
24. Matsui H, Yudoh K, Tsuji H (1996) Significance of serum levels of type I procollagen peptide and intact osteocalcin and bone mineral density in patients with ossification of the posterior longitudinal ligaments. Calcif Tissue Int 59:397–400
25. Brownlee M (1995) Advanced protein glycosylation in diabetes and aging. Annu Rev Med 46:223–234
26. Brownlee M, Cerami A, Vlassara H (1988) Advanced glycosylation end products in tissue and the biochemical basis of diabetic complications. N Engl J Med 318:1315–1321
27. Hernandez CJ, Tang SY, Baumbach BM, Hwu PB, Sakkee AN, van der Ham F, DeGroot J, Bank RA, Keaveny TM (2005) Trabecular microfracture and the influence of pyridinium and non-enzymatic glycation-mediated collagen crosslinks. Bone 37:825–832
28. Wang X, Shen X, Li X, Agrawal CM (2002) Age-related changes in the collagen network and toughness of bone. Bone 31:1–7
29. Viguet-Carrin S, Roux JP, Arlot ME, Merabet Z, Leeming DJ, Byrjalsen I, Delmas PD, Bouxsein ML (2006) Contribution of the advanced glycation end product pentosidine and of maturation of type I collagen to compressive biomechanical properties of human lumbar vertebrae. Bone 39:1073–1079
30. Yamamoto M, Yamaguchi T, Yamauchi M, Yano S, Sugimoto T (2008) Serum pentosidine levels are positively associated with the presence of vertebral fractures in postmenopausal women with type 2 diabetes. J Clin Endocrinol Metab 93:1013–1019
31. Hricik DE, Schulak JA, Sell DR, Fogarty JF, Monnier VM (1993) Effects of kidney or kidney–pancreas transplantation on plasma pentosidine. Kidney Int 43:398–403
32. Sugiyama S, Miyata T, Ueda Y, Tanaka H, Maeda K, Kawashima S, Ypersele V, de Strihou C, Kurokawa K (1998) Plasma levels of pentosidine in diabetic patients: an advanced glycation end product. J Am Soc Nephrol 9:1681–1688
33. Miyata T, Ueda Y, Shinzato T, Iida Y, Tanaka S, Kurokawa K, van Ypersele de Strihou C, Maeda K (1996) Accumulation of albumin-linked and free-form pentosidine in the circulation of uremic patients with end-stage renal failure: renal implications in the pathophysiology of pentosidine. J Am Soc Nephrol 7:1198–1206
34. Hirai N, Ikata T, Murase M, Morita T, Katoh S (1995) Bone mineral density of the lumbar spine in patients with ossification of the posterior longitudinal ligament of the cervical spine. J Spinal Disord 8:337–341
35. Yamauchi T, Taketomi E, Matsunaga S, Sakou T (1999) Bone mineral density in patients with ossification of the posterior

longitudinal ligament in the cervical spine. J Bone Miner Metab 17:296–300

36. Morio Y, Yamamoto K, Kishimoto H, Hagino H, Kuranobu K, Kagawa T (1993) Bone mineral density of the radius in patients with ossification of the cervical posterior longitudinal ligament. A longitudinal study. Spine 18:2513–2516
37. Havelka S, Vesela M, Pavelkova A, Ruzickova S, Koga H, Maeda S, Inoue I, Halman L (2001) Are DISH and OPLL genetically related? Ann Rheum Dis 60:902–903
38. Chiba K, Yamamoto I, Hirabayashi H, Iwasaki M, Goto H, Yonenobu K, Toyama Y (2005) Multicenter study investigating the postoperative progression of ossification of the posterior longitudinal ligament in the cervical spine: a new computer-assisted measurement. J Neurosurg Spine 3:17–23
39. Murakami M, Seichi A, Chikuda H, Takeshita K, Nakamura K, Kimura A (2010) Long-term follow-up of the progression of ossification of the posterior longitudinal ligament. Case report. J Neurosurg Spine 12:577–579

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Medline Indexed

Geriatr Gerontol Int 2014; **14:** *695–701*

ORIGINAL ARTICLE: SOCIAL RESEARCH, PLANNING AND PRACTICE

Incidence of certified need of care in the long-term care insurance system and its risk factors in the elderly of Japanese population-based cohorts: The ROAD study

Toru Akune,[1] Shigeyuki Muraki,[1] Hiroyuki Oka,[2] Sakae Tanaka,[3] Hiroshi Kawaguchi,[3] Fumiaki Tokimura,[4] Hideyo Yoshida,[5] Takao Suzuki,[6] Kozo Nakamura[7] and Noriko Yoshimura[2]

Departments of [1]Clinical Motor System Medicine and [2]Joint Disease Research, 22nd Century Medical & Research Center, Graduate School of Medicine, University of Tokyo, [3]Department of Sensory & Motor System Medicine, Graduate School of Medicine, University of Tokyo, [4]Department of Orthopaedic Surgery, Tokyo Metropolitan Geriatric Hospital, [5]Research Team for Promoting Independence of the Elderly, Tokyo Metropolitan Institute of Gerontology, Tokyo, [6]Research Institute, National Center for Geriatrics and Gerontology, Aichi, and [7]National Rehabilitation Center for Persons with Disabilities, Saitama, Japan

Aim: To examine the incidence of certified need of care in the national long-term care insurance (LTCI) system, and to determine its risk factors in the elderly of Japanese population-based cohorts of the Research on Osteoarthritis/Osteoporosis Against Disability (ROAD) study.

Methods: Of the 3040 participants in the baseline examination of the ROAD study, we enrolled 1773 (699 men, 1074 women) aged 65 years or older who were not certified as in need of care level elderly at baseline. Participants were followed for incident certification of need of care in the LTCI system. Associated factors in the baseline examination with occurrence were determined by multivariate Cox proportional hazards regression analysis. Muscle dysfunction was defined in accordance with the European Working Group on Sarcopenia in Older People algorithm for screening sarcopenia.

Results: A total of 54 men and 115 women were certified as in need of care level elderly during the average 4.0-year follow up. The incidence was 2.0 and 2.5 per 100 person-years in men and women, respectively. Identified risk factors were region, age, body mass index <18.5 or ≥27.5 kg/m^2, grip strength, knee extension torque, usual gait speed, chair stand time and muscle dysfunction.

Conclusions: Both underweight and obesity, as well as low muscle strength and physical ability, are risk factors for certification of need of care. Considering muscle dysfunction is a risk factor for occurrence, screened individuals are recommended to receive early intervention programs regardless of muscle volume. **Geriatr Gerontol Int 2014; 14: 695–701.**

Keywords: activities of daily living, certification of need of care (*youkaigo-nintei*), disability, long-term care insurance system, prospective cohort study.

Introduction

Japan is a super-aged society experiencing an unprecedented aging of the population. The proportion of the population aged 65 years or older was 23% in 2010, and is expected to reach 30.1% in 2024 and 39% in 2051.[1] This leads to an increasing proportion of disabled elderly requiring support or long-term care, imposing enormous economic and social burdens on the country. The Japanese Government started the national long-term care insurance (LTCI) system in 2000 based on the Long-Term Care Insurance Act.[2] The aim was to certify need of care level elderly, and to provide suitable care services according to the level of care required (seven levels, including requiring support [levels 1 and 2] and requiring long-term care [levels 1–5]). The total number of certified in need of care level elderly was reported to be 5 million in 2011.[2]

Accepted for publication 12 August 2013.

Correspondence: Dr Toru Akune MD PhD, Department of Clinical Motor System Medicine, 22nd Century Medical and Research Center, Graduate School of Medicine, University of Tokyo, Hongo 7-3-1, Bunkyo-ku, Tokyo 113-8655, Japan. Email: akune-ort@h.u-tokyo.ac.jp

Certification of need of care in the national LTCI system is an important outcome in Japan, not only because of its massive social and economic burdens, but also because it is urgently required to reduce its risk and decrease the number of disabled elderly requiring care in their activities of daily living (ADL). For establishment of an evidence-based prevention strategy, it is critically important to accumulate epidemiological evidence including the incidence of certified need of care and identification of risk factors. However, there have been no studies to clarify the incidence of certified need of care in the LTCI system or its risk factors using large-scale, population-based cohorts.

In 2005, we started a large-scale, population-based cohort study entitled the Research on Osteoarthritis/Osteoporosis Against Disability (ROAD) study with a total of 3040 participants, which aims to elucidate the environmental and genetic backgrounds of musculoskeletal diseases.[3,4] The present study investigated the incidence of certified need of care in the national LTCI system, and determined its risk factors using a database from the ROAD study.

Methods

Participants

The present analysis was based on data collected from cohorts established in 2005 for the ROAD study. Details of the cohorts have been reported elsewhere.[3,4] Briefly, we created a baseline database from 2005–2007, which included clinical and genetic information on 3040 residents of Japan (1061 men, 1979 women). Participants were recruited from resident registration listings in three communities, namely, an urban region in Itabashi, Tokyo, and rural regions in Hidakagawa and Taiji, Wakayama. Participants in the urban region in Itabashi were recruited from those of a cohort study,[5] in which participants were randomly drawn from the register database of Itabashi ward residents, with a response rate of 75.6% in the group aged >60 years. Participants in the rural regions in Hidakagawa and Taiji were recruited from resident registration lists, with response rates of 68.4% and 29.3%, respectively, in the groups aged >60 years. Inclusion criteria were the ability to: (i) walk to the survey site; (ii) report data; and (iii) understand and sign an informed consent form. For the present study, we enrolled 1773 participants (699 men, 1074 women; mean age 75.4 years) aged 65 years or older who were not certified as need of care level elderly in the national LTCI system at baseline. All participants provided written informed consent, and the study was carried out with approval from the ethics committees of the University of Tokyo and the Tokyo Metropolitan Institute of Gerontology.

Baseline procedures

Participants completed an interviewer-administered questionnaire containing 400 items that included lifestyle information, such as smoking habits, alcohol consumption and physical activity. At baseline, anthropometric measurements, including height and weight, were taken, and body mass index (BMI; weight [kg]/height^2 [m^2]) was estimated based on the measured height and weight. Underweight was defined as BMI <18.5 and obesity as BMI ≥27.5, according to the 2004 consensus statement from the WHO regarding appropriate BMI for Asian populations.[6] Grip strength was measured on bilateral sides using a handgrip dynamometer (TOEI LIGHT, Saitama, Japan); the higher measurement was recorded. Isometric peak knee extension torque was measured at a knee flexion angle of 90° using a dynamometer (GT-30; OG GIKEN, Okayama, Japan) twice in participants from the urban regional cohort (Itabashi, Tokyo); the higher measurement was recorded. The time taken to walk 6 m at usual walking speed in a hallway was recorded, and usual gait speed was calculated. Skeletal muscle dysfunction was defined as usual gait speed ≤0.8 m/s or grip strength <30 kg in men and <20 kg in women, according to the algorithm for screening sarcopenia recommended by the European Working Group on Sarcopenia in Older People (EWGSOP).[7,8] The time taken for five consecutive chair rises without the use of hands was recorded in the rural regional cohorts (Hidakagawa and Taiji, Wakayama). Hands were folded in front of the chest with feet flat on the floor. Timing began with the command "Go", and ended when the buttocks contacted the chair on the fifth landing.

Certification of need of care in the LTCI system

The nationally uniform criteria for long-term care need certification was established objectively by the Japanese Government, and certification of need of care level elderly is determined based on evaluation results by the Certification Committee for Long-term Care Need in municipalities in accordance with basic guidelines formulated by the Government. The process of eligibility for certification of need of care in the LTCI system was described in detail by Chen *et al.*[9] An elderly person who requires help with ADL or the caregiver contacts the municipal Government to request official certification of care needs. After the application, a trained official visits the home to assess the current physical status of the elderly person, including the presence or absence of muscle weakness or joint contracture of limbs, and difficulties in sitting-up, standing-up, maintaining sitting or standing position, transferring from one place to another, standing on one leg, walking, bathing, dressing, and other ADL. Mental status, including dementia, is also assessed. These data are analyzed to calculate a

Table 1 Baseline characteristics of population at risk for certified need of care in the long-term care insurance system

	Entire cohort		Urban cohort		Rural cohort	
	Men	Women	Men	Women	Men	Women
No. participants	699	1,074	333	486	366	588
Age (years)	75.6 (5.1)	75.2 (5.3)	77.5 (3.7)	77.3 (3.8)	73.8 (5.5)†	73.5 (5.8)†
Height (cm)	160.9 (6.0)	147.9 (6.0)*	161.0 (5.8)	148.2 (5.4)*	160.8 (6.2)	147.7 (6.5)*
Weight (kg)	59.4 (9.1)	50.0 (8.3)*	59.4 (8.2)	49.8 (7.8)*	59.4 (9.9)	50.1 (8.8)*
BMI (kg/m^2)	22.9 (2.9)	22.8 (3.4)	22.9 (2.7)	22.7 (3.3)	22.9 (3.1)	22.9 (3.5)
BMI <18.5 (%)	6.2	8.0	6.1	7.9	6.3	8.0
BMI ≥27.5 (%)	5.7	9.3**	3.9	8.5**	7.4	9.9
Grip strength (kg)	30.4 (6.8)	19.4 (4.9)*	28.6 (6.1)	18.2 (4.1)*	31.9 (7.0)†	20.3 (5.2)*†
Knee extension torque (kgm)	–	–	79.6 (27.2)	54.8 (17.0)*	–	–
Usual gait speed (m/s)	1.17 (0.31)	1.10 (0.33)*	1.27 (0.24)	1.22 (0.24)*	1.08 (0.34)†	1.00 (0.36)*†
Chair stand time (s)	–	–	–	–	10.8 (3.7)	12.2 (5.4)*
Muscle dysfunction (%)§	48.7	56.0**	52.6	60.0**	45.2	52.6**‡
Smoking (%)	21.0	3.2**	19.2	3.0**	22.6	3.4**
Alcohol consumption (%)	61.2	23.0**	61.0	28.8**	61.3	18.4**‡

Except where indicated otherwise, values are mean (SD). *$P < 0.05$ versus men in the corresponding group of the same cohort by unpaired Student's *t*-test. **$P < 0.05$ versus men in the corresponding group of the same cohort by χ^2-test. †$P < 0.05$ versus urban cohort in the corresponding group of the same sex by unpaired Student's *t*-test. ‡$P < 0.05$ versus urban cohort in the corresponding group of the same sex by χ^2-test. §Muscle dysfunction was defined as usual gait speed ≤0.8 m/s or grip strength <30 kg in men and <20 kg in women. BMI, body mass index; LTCI, long-term care insurance system.

standardized score for determination of the level of care needs (certified support, levels 1–2; or long-term care, levels 1–5). In addition, the primary physician of the applicant assesses physical and mental status, including information on diseases causing ADL disability and the extent of disabilities caused by them. Finally, the Certification Committee for Long-term Care Need reviews the data and determines the certification and its level.

Follow up and definition of incident certified need of care

After the baseline ROAD survey, participants who were not certified as need of care level elderly at baseline were followed for incident certification of need of care in the LTCI system. Incident certified need of care was defined as the incident certified 7 level, including requiring support (levels 1–2) and requiring long-term care (levels 1–5). Information on the presence or absence of certification of need of care and its date of occurrence were collected by the resident registration listings in three communities every year up to 2010, and were used for analyses in the present study.

Statistical analysis

All statistical analyses were carried out using STATA statistical software (STATA, College Station, TX, USA). Differences in the values of the parameters between two groups were tested for significance using the non-paired Student's *t*-test and χ^2-test. Factors associated with occurrence of certified need of care were determined using Cox proportional hazards regression analysis; hazard ratios (HR) and 95% confidence intervals (CI) were determined after adjusting for region, age, sex, and BMI.

Results

Of the 1773 participants who were not certified as in need of care level elderly at baseline, information on certification of need of care could be obtained in 1760 (99.3%) during the average 4.0-year follow up. A total of 54 men and 115 women were certified as in need of care level elderly in the national LTCI system; whereas, 1591 remained uncertified during the follow-up period. A total of 126 participants died, and eight moved away.

Table 1 shows the baseline characteristics of the population at risk for occurrence of certified need of care in the LTCI system. Although BMI was not significantly different between men and women in the entire, urban or rural cohorts, prevalence of obesity (BMI ≥27.5) was significantly higher in women than in men in the entire and urban cohorts. The prevalence of underweight was higher in women than in men in the entire,

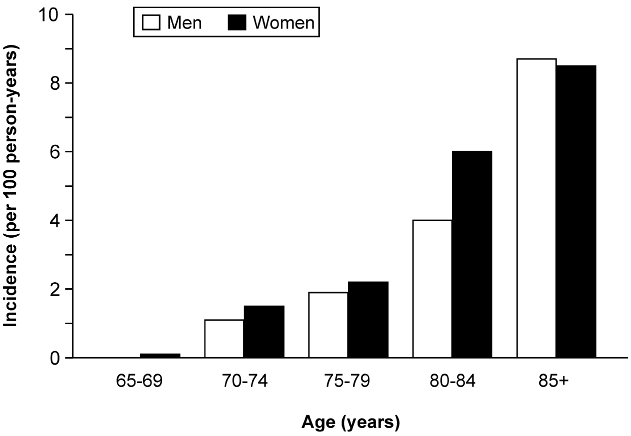

Figure 1 Incidence of certified need of care in the long-term care insurance system in men and women in each age stratum.

urban and rural cohorts; however, there was no significant difference. The prevalence of skeletal muscle dysfunction, determined by gait speed and grip strength, was significantly higher in women than in men in the entire, urban and rural cohorts.

Figure 1 shows sex- and age-distributions of the incidence of certified need of care in the LTCI system. Incidence was 2.3/100 person-years in the overall population of the entire cohort, and 2.0/100 person-years in men and 2.5/100 person-years in women. The incidence was very low in the age-stratum of 65–69 years, whereas, it tended to be markedly higher in the age-strata of 80 years and older in both sexes.

We then determined the risk factors for occurrence of certified need of care in the LTCI system. First, analysis was carried out using region, age, sex and BMI as explanatory variables in the Cox proportional hazards regression model (upper part of Table 2). Rural region and age were found to be risk factors for occurrence of certified need of care in the overall population. Sex and BMI were not significantly different. To further investigate the association between BMI and occurrence, we categorized BMI into three groups. Both underweight (BMI <18.5) and obesity (BMI ≥27.5) were found to be risk factors for occurrence of certified need of care, showing a U-shaped association. As for muscle strength and physical performance, handgrip strength, knee extension torque, usual gait speed, chair stand time and muscle dysfunction were found to be significantly associated with occurrence of certified need of care (lower part of Table 2). We carried out the same analyses in men and women separately (Table 2), and found results similar to those of the overall population.

Discussion

The present study investigated the incidence of certified need of care in the national LTCI system, and

Table 2 Hazard ratios and 95% confidence intervals for occurrence of certified need of care in the long-term care insurance system

	Overall population		Men		Women	
	Crude HR (95% CI)	Adjusted HR (95% CI)	Crude HR (95% CI)	Adjusted HR (95% CI)	Crude HR (95% CI)	Adjusted HR (95% CI)
Region (rural *vs* urban)	1.15 (0.83–1.59)	1.61 (1.17–2.24)[b]	1.13 (0.65–1.96)	1.64 (0.94–2.86)[g]	1.15 (0.77–1.72)	1.59 (1.07–2.38)[g]
Age (+1 year)	1.17 (1.13–1.20)	1.17 (1.14–1.21)[c]	1.19 (1.12–1.26)	1.19 (1.13–1.26)[h]	1.16 (1.12–1.20)	1.16 (1.12–1.21)[h]
Sex (women *vs* men)	1.25 (0.90–1.74)	1.24 (0.89–1.73)[d]	–	–	–	–
BMI (+1 kg/m^2)	0.98 (0.93–1.03)	1.01 (0.96–1.06)[e]	0.93 (0.84–1.02)	0.96 (0.88–1.06)[i]	1.00 (0.94–1.06)	1.02 (0.97–1.08)[i]
≥18.5 or <27.5	1 (Reference)	1 (Reference)	1 (Reference)	1 (Reference)	1 (Reference)	1 (Reference)
BMI <18.5	2.10 (1.31–3.38)	1.77 (1.10–2.84)[e]	2.43 (1.09–5.40)	1.69 (0.75–3.82)[i]	1.93 (1.07–3.48)	1.79 (0.99–3.22)[i]
BMI ≥27.5	1.82 (1.13–2.93)	2.12 (1.32–3.43)[e]	1.39 (0.50–3.87)	1.91 (0.68–5.38)[i]	1.92 (1.12–3.29)	2.18 (1.27–3.75)[i]
Grip strength (+1 kg)	0.93 (0.91–0.95)	0.94 (0.91–0.97)[f]	0.91 (0.87–0.95)	0.94 (0.89–0.99)[j]	0.89 (0.85–0.92)	0.94 (0.89–0.98)[j]
Knee extension torque (+1 kgm)	0.97 (0.96–0.99)	0.97 (0.96–0.99)[f]	0.97 (0.95–0.99)	0.97 (0.95–0.99)[j]	0.97 (0.95–0.99)	0.97 (0.95–1.00)[j]
Usual gait speed (+0.1 m/s)	0.80 (0.77–0.85)	0.84 (0.79–0.90)[f]	0.81 (0.74–0.88)	0.83 (0.74–0.92)[j]	0.80 (0.76–0.85)	0.85 (0.78–0.92)[j]
Chair stand time (+1 s)	1.09 (1.07–1.12)	1.06 (1.03–1.10)[f]	1.18 (1.10–1.27)	1.11 (1.03–1.21)[j]	1.09 (1.06–1.11)	1.06 (1.02–1.09)[j]
Muscle dysfunction (yes *vs* no)[a]	2.91 (2.02–4.19)	1.71 (1.16–2.52)[f]	2.60 (1.45–4.68)	1.68 (0.91–3.09)[j]	3.07 (1.92–4.92)	1.72 (1.04–2.85)[j]
Smoking (yes *vs* no)	0.98 (0.58–1.68)	1.39 (0.79–2.43)[f]	1.18 (0.62–2.26)	1.54 (0.79–3.01)[j]	0.95 (0.30–2.99)	1.09 (0.35–3.47)[j]
Alcohol consumption (yes *vs* no)	0.71 (0.50–0.99)	0.83 (0.58–1.21)[f]	0.78 (0.45–1.35)	0.93 (0.53–1.61)[j]	0.70 (0.42–1.16)	0.76 (0.46–1.27)[j]

[a]Muscle dysfunction was defined as usual gait speed ≤0.8 m/s or grip strength <30 kg in men and <20 kg in women. [b]Adjusted for age, sex and body mass index (BMI). [c]Adjusted for region, sex and BMI. [d]Adjusted for region, age and BMI. [e]Adjusted for region, age and sex. [f]Adjusted for region, age, sex and BMI. [g]Adjusted for age and BMI. [h]Adjusted for region and BMI. [i]Adjusted for region and age. [j]Adjusted for region, age and BMI. Urban region and men were used as references. CI, confidence interval; HR, hazard ratio.

determined its risk factors using Japanese population-based cohorts. Identified risk factors were region, age, underweight, obesity, handgrip strength, knee extension torque, usual gait speed, chair stand time and muscle dysfunction (determined by the EWGSOP algorithm for screening sarcopenia).

In the present study, we could not obtain information on causes of certified need of care in the LTCI system. Therefore, we could not analyze the direct association of each causing condition with such factors as anthropometric and physical performance measurements. The Government of Japan reported that the top five leading causes of certified need of care were cerebral stroke, dementia, asthenia as a result of older age, joint disease and fall-related fracture, comprising 71.6% of all causes in 2010.[10] Based on these data, most of the causes of incident certification in the present study are inferred to be among the top five leading conditions.

Both low and high BMI were found to be risk factors for occurrence of certified need of care, showing an overall U-shaped association. This U-shaped association is similar to that between BMI and risk of death.[11,12] The association between risk of death from cardiovascular disease and other causes, and BMI was reported to be U-shaped in East Asians,[11] whereas the risk of all-cause mortality versus BMI was also found to have a U-shaped association in Western European and North American populations.[12] High BMI is an established risk factor for chronic diseases, including hypertension, dyslipidemia and diabetes mellitus, which increase the risk of cerebral stroke.[13] High BMI is also a major risk factor for knee osteoarthritis,[14–17] which can cause ADL disability in the elderly.[18] In contrast, low BMI is an established risk factor for osteoporosis and related fracture.[19] It also might relate to asthenia, a condition of loss or lack of bodily strength as a result of chronic wasting disease. Underweight as a result of malnutrition or sarcopenia is suggested to be included in this category.

Other identified risk factors were handgrip strength, knee extension torque, usual gait speed, chair stand time and muscle dysfunction (determined by the EWGSOP algorithm for screening sarcopenia). Previous studies have reported that low muscle strength and physical performance were predictors of subsequent ADL disability in the elderly.[20–23] The results of the present study are consistent with these previous reports. As many of the performance tests used in the present study are easy to carry out and evaluate, they can be utilized for screening elderly persons at high risk of certified need of care in the LTCI system. Those who were classified as having muscle dysfunction in the present study were at high risk of sarcopenia as well as certified need of care, regardless of muscle volume. Therefore, elderly persons screened by the EWGSOP algorithm are recommended to receive early intervention programs for prevention of ADL disability and subsequent deterioration leading to certified need of care.

The Japanese Orthopedic Association proposed the concept of "locomotive syndrome" in 2007 for the promotion of preventive health care of locomotive organs.[24–26] Locomotive syndrome refers to conditions under which the elderly have been receiving support or long-term care, or high-risk conditions under which they might soon require support or long-term care, that are caused by musculoskeletal disorders.[24–26] Functional declines in locomotive organs, including muscle strength, walking speed and balancing ability, usually progress slowly and gradually. As such, it might be difficult for people to recognize this decline in their daily life. Therefore, it is of particular importance to raise awareness of the growing risk caused by these disorders, and to take action to improve and maintain the health of locomotive organs. Population approaches, including promotion of the concept of locomotive syndrome to both younger and older generations, are important, in addition to high-risk approaches, including identifying those at risk for certified need of care and practicing intervention programs to reduce the risk of certified need of care.

There were some limitations in the present study. As we could not obtain information on causing conditions, we could not determine the risk factors for occurrence of certified need of care with respect to each causing condition. Additional studies are necessary to identify those direct associations. In the present study, the rural region was at higher risk of incident certified need of care compared with the urban region. The reasons for this could include differences in available public and private transportation or delivery services regarding meals and commodities for the elderly. In addition to these, the threshold between certified and non-certified elderly might be different among municipalities, which could lead to regional differences. Although the Certification Committee for Long-term Care Need in each municipality determines certification in accordance with guidelines formulated by the Government, the Committee also has to consider assessment by the applicant's primary physician and objective evaluation results regarding physical and mental status, which could affect the threshold of certification. Another limitation was health bias. Participants at baseline in the present study were those who could walk to the survey site, and could understand and sign an informed consent form. As those who could not were not included in the analyses, the study participants do not truly represent the general population due to health bias. Therefore, incidence of certified need of care was most likely underestimated, which should be taken into consideration when generalizing the results of the present study.

In conclusion, the present study revealed the incidence of certified need of care in the national LTCI system, and determined its risk factors using Japanese population-based cohorts. Both underweight and obesity were found to be risk factors for certified need of care, suggesting that maintenance of intermediate BMI is important for prevention. Low muscle strength and physical ability were also shown to be risk factors for certified need of care. Physical performance measures identified as predictors can be used as screening tools to identify high-risk individuals. Considering muscle dysfunction, screened by the EWGSOP algorithm, was a risk factor for occurrence, screened individuals are recommended to receive early intervention programs regardless of muscle volume. Further studies are necessary to develop intervention programs and to test their effectiveness, along with accumulation of epidemiological evidence, to prevent certified need of care and reduce the social and economic burdens associated with this condition.

Acknowledgments

This study was supported by Grants-in-Aid for Scientific Research (S19109007, B20390182, B23390172, B23390356, and B23390357) from the Japanese Ministry of Education, Culture, Sports, Science and Technology; H17-Men-eki-009, H18-Choujyu-037, H20-Choujyu-009, H21-Chouju-Wakate-011, H22-Chouju-Wakate-007, H23-Chouju-002, and H25-Chouju-007 from the Ministry of Health, Labour and Welfare; and Research Aid from the Japanese Orthopaedic Association (JOA-Subsidized Science Project Research 2006-1 and 2010-2).

Disclosure statement

The authors declare no conflict of interest.

References

1 National Institute of Population and Society Research. Population projections for Japan (January 2012): 2011 to 2060. [Cited 18 Jun 2013.] Available from URL: http://www.ipss.go.jp/site-ad/index_english/esuikei/gh2401e.asp
2 Ministry of Health, Labour and Welfare. Long-term care, health and welfare services for the elderly. [Cited 18 Jun 2013.] Available from URL: http://www.mhlw.go.jp/english/policy/care-welfare/care-welfare-elderly/index.html
3 Yoshimura N, Muraki S, Oka H, Kawaguchi H, Nakamura K, Akune T. Cohort profile: research on Osteoarthritis/Osteoporosis Against Disability study. *Int J Epidemiol* 2010; **39**: 988–995.
4 Yoshimura N, Muraki S, Oka H *et al*. Prevalence of knee osteoarthritis, lumbar spondylosis, and osteoporosis in Japanese men and women: the research on osteoarthritis/osteoporosis against disability study. *J Bone Miner Metab* 2009; **27**: 620–628.
5 Shimada H, Lord SR, Yoshida H *et al*. Predictors of cessation of regular leisure-time physical activity in community-dwelling elderly people. *Gerontology* 2007; **53**: 293–297.
6 WHO Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet* 2004; **363**: 157–163.
7 Cruz-Jentoft AJ, Baeyens JP, Bauer JM *et al*. European Working Group on Sarcopenia in Older People. Sarcopenia: European consensus on definition and diagnosis: report of the European Working Group on sarcopenia in older people. *Age Ageing* 2010; **39**: 412–423.
8 Lauretani F, Russo CR, Bandinelli S *et al*. Age-associated changes in skeletal muscles and their effect on mobility: an operational diagnosis of sarcopenia. *J Appl Physiol* 2003; **95**: 1851–1860.
9 Chen W, Fukutomi E, Wada T *et al*. Comprehensive geriatric functional analysis of elderly populations in four categories of the long-term care insurance system in a rural, depopulated and aging town in Japan. *Geriatr Gerontol Int* 2013; **13**: 63–69.
10 Ministry of Health, Labour and Welfare. The outline of the results of National Livelihood Survey 2010. [Cited 18 Jun 2013.] Available from URL: http://www.mhlw.go.jp/toukei/saikin/hw/k-tyosa/k-tyosa10/4-2.html
11 Zheng W, McLerran DF, Rolland B *et al*. Association between body-mass index and risk of death in more than 1 million Asians. *N Engl J Med* 2011; **364**: 719–729.
12 Prospective Studies Collaboration, Whitlock G, Lewington S, Sherliker P *et al*. Body-mass index and cause-specific mortality in 900 000 adults: collaborative analyses of 57 prospective studies. *Lancet* 2009; **373**: 1083–1096.
13 Haslam DW, James WP. Obesity. *Lancet* 2005; **366**: 1197–1209.
14 Davis MA, Ettinger WH, Neuhaus JN, Cho SA, Hauck WW. The association of knee injury and obesity with unilateral and bilateral osteoarthritis of the knee. *Am J Epidemiol* 1989; **130**: 278–288.
15 Felson DT, Zhang Y, Hannan MT *et al*. Risk factors for incident radiographic knee osteoarthritis in the elderly: the Framingham Study. *Arthritis Rheum* 1997; **40**: 728–733.
16 Muraki S, Oka H, Akune T *et al*. Prevalence of radiographic knee osteoarthritis and its association with knee pain in the elderly of Japanese population-based cohorts: the ROAD study. *Osteoarthritis Cartilage* 2009; **17**: 1137–1143.
17 Muraki S, Akune T, Oka H *et al*. Incidence and risk factors for radiographic knee osteoarthritis and knee pain in Japanese men and women: a longitudinal population-based cohort study. *Arthritis Rheum* 2012; **64**: 1447–1456.
18 Sharma L, Kapoor D. Epidemiology of osteoarthritis. In: Moskowitz RW, Altman RD, Hochberg MC, Buckwalter JA, Goldberg VM, eds. *Osteoarthritis: Diagnosis and Medical/Surgical Management*, 4th edn. Philadelphia, PA: Lippincott Williams & Wilkins, 2007; 3–26.
19 De Laet C, Kanis JA, Odén A *et al*. Body mass index as a predictor of fracture risk: a meta-analysis. *Osteoporos Int* 2005; **16**: 1330–1338.
20 Guralnik JM, Ferrucci L, Simonsick EM, Salive ME, Wallace RB. Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. *N Engl J Med* 1995; **332**: 556–561.
21 Giampaoli S, Ferrucci L, Cecchi F *et al*. Hand-grip strength predicts incident disability in non-disabled older men. *Age Ageing* 1999; **28**: 283–288.
22 Onder G, Penninx BW, Ferrucci L, Fried LP, Guralnik JM, Pahor M. Measures of physical performance and risk for

progressive and catastrophic disability: results from the Women's Health and Aging Study. *J Gerontol A Biol Sci Med Sci* 2005; **60**: 74–79.

23 Vermeulen J, Neyens JC, van Rossum E, Spreeuwenberg MD, de Witte LP. Predicting ADL disability in community-dwelling elderly people using physical frailty indicators: a systematic review. *BMC Geriatr* 2011; **11**: 33.

24 Nakamura KA. "super-aged" society and the "locomotive syndrome". *J Orthop Sci* 2008; **13**: 1–2.

25 Nakamura K. Locomotive syndrome: disability-free life expectancy and locomotive organ health in a "super-aged" society. *J Orthop Sci* 2009; **14**: 1–2.

26 Nakamura K. The concept and treatment of locomotive syndrome: its acceptance and spread in Japan. *J Orthop Sci* 2011; **16**: 489–491.

J Orthop Sci (2014) 19:489–496
DOI 10.1007/s00776-014-0537-z

ORIGINAL ARTICLE

Association of physical activities of daily living with the incidence of certified need of care in the long-term care insurance system of Japan: the ROAD study

Toru Akune · Shigeyuki Muraki · Hiroyuki Oka · Sakae Tanaka · Hiroshi Kawaguchi · Fumiaki Tokimura · Hideyo Yoshida · Takao Suzuki · Kozo Nakamura · Noriko Yoshimura

Received: 26 August 2013 / Accepted: 16 January 2014 / Published online: 8 February 2014

Abstract

Background The present study aimed to investigate association of physical activities of daily living with the incidence of certified need of care in the national long-term care insurance (LTCI) system in elderly Japanese population-based cohorts.

Methods Of the 3,040 participants in the baseline examination, we enrolled 1,773 (699 men, 1,074 women) aged 65 years or older who were not certified as in need of care-level elderly at baseline. Participants were followed during an average of 4.0 years for incident certification of need of care in the LTCI system. The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) was used assess function. Associated factors in the baseline examination with the occurrence were determined by multivariate Cox proportional hazards regression analysis. Receiver operating characteristic curve analysis was performed to evaluate cut-off values for discriminating between the occurrence and the non-occurrence group.

Results All 17 items in the WOMAC function domain were significantly associated with the occurrence of certified need of care in the overall population. Cut-off values of the WOMAC function score that maximized the sum of sensitivity and specificity were around 4–6 in the overall population, in men, and in women. Multivariate Cox hazards regression analysis revealed that a WOMAC function score $\geq$4 was significantly associated with occurrence with the highest hazard ratio (HR) for occurrence after adjusting for confounders in the overall population (HR [95 % confidence interval (CI)] 2.54 [1.76–3.67]) and in women [HR (95 % CI) 3.13 (1.95–5.02)]. A WOMAC function score $\geq$5 was significantly associated with the highest HR for occurrence in men [HR (95 % CI) 1.88 (1.03–3.43)].

Conclusions Physical dysfunction in daily living is a predictor of the occurrence of certified need of care. Elderly men with a WOMAC function score $\geq$5 and women with a score $\geq$4 should undergo early intervention programs to prevent subsequent deterioration.

T. Akune (✉) · S. Muraki
Department of Clinical Motor System Medicine, 22nd Century Medical and Research Center, Graduate School of Medicine, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8655, Japan
e-mail: akune-ort@h.u-tokyo.ac.jp

H. Oka · N. Yoshimura
Department of Joint Disease Research, 22nd Century Medical and Research Center, Graduate School of Medicine, University of Tokyo, Tokyo, Japan

S. Tanaka · H. Kawaguchi
Department of Sensory and Motor System Medicine, Graduate School of Medicine, University of Tokyo, Tokyo, Japan

F. Tokimura
Department of Orthopaedic Surgery, Tokyo Metropolitan Geriatric Hospital, Tokyo, Japan

H. Yoshida
Research Team for Promoting Independence of the Elderly, Tokyo Metropolitan Institute of Gerontology, Tokyo, Japan

T. Suzuki
Research Institute, National Center for Geriatrics and Gerontology, Aichi, Japan

K. Nakamura
National Rehabilitation Center for Persons with Disabilities, Saitama, Japan

Introduction

Japan is a super-aged society experiencing an unprecedented aging of the population. The proportion of the population aged 65 years or older was 23 % in 2010, and is expected to reach 30.1 % in 2024 and 39 % in 2051 [1]. This leads to an increasing proportion of disabled elderly requiring support or long-term care, imposing enormous economic and social burdens on the country. The Japanese Government started the national long-term care insurance (LTCI) system in 2000 based on the Long-Term Care Insurance Act [2]. The aim was to certify need of care-level elderly and to provide suitable care services according to the level of care required [7 levels, including requiring support (levels 1 and 2) and requiring long-term care (levels 1–5)]. The total number of certified need of care-level elderly was reported to be 5 million in 2011 [2]. Certification of need of care in the national LTCI system is an important outcome in Japan not only because of its massive social and economic burdens, but also because it is urgently necessary to reduce risk and decrease the number of disabled elderly requiring care in their activities of daily living (ADLs). It is critically important to accumulate epidemiologic evidence, including identification of predictors, to establish evidence-based prevention strategies. However, no studies have determined the association of physical ADLs with the incidence of certified need of care in the national LTCI system using large-scale, population-based cohorts. The objective of the present study was to investigate the association of physical ADLs with the incidence of certified need of care in the national LTCI system and determine its predictors in elderly participants of large-scale, population-based cohorts of the research on osteoarthritis/osteoporosis against disability (ROAD) study.

Subjects and methods

Participants

The analysis was based on data collected from cohorts established in 2005 for the ROAD study. Details of the cohorts have been reported elsewhere [3, 4]. Briefly, a baseline database was created from 2005 to 2007, which included clinical and genetic information on 3,040 residents of Japan (1,061 men, 1,979 women). Participants were recruited from resident registration listings in three communities, namely, an urban region in Itabashi, Tokyo, and rural regions in Hidakagawa and Taiji, Wakayama. Participants in the urban region in Itabashi were recruited from those of a cohort study [5] in which the participants were randomly drawn from the register database of Itabashi ward residents, with a response rate in the age group >60 years of 75.6 %. Participants in the rural regions in Hidakagawa and Taiji were recruited from resident registration lists, with response rates in the groups aged >60 years of 68.4 and 29.3 %, respectively. Inclusion criteria were the ability to (1) walk to the survey site, (2) report data, and (3) understand and sign an informed consent form. For the present study, we enrolled 1,773 participants (699 men, 1,074 women; mean age 75.4 years) aged 65 years or older who were not certified as in need of care-level elderly in the national LTCI system at baseline. All participants provided written informed consent, and the study was conducted with approval from the ethics committees of the participating institutions.

Baseline procedures

Participants completed an interviewer-administered questionnaire containing 400 items that included lifestyle information, such as smoking habits, alcohol consumption, and physical activity. At baseline, anthropometric measurements, including height and weight, were taken, and body mass index (BMI) [weight (kg)/height^2 (m^2)] was estimated based on the measured height and weight.

Assessment of physical ADLs

We used the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) for assessment of physical ADLs. The WOMAC is a health status instrument, consisting of three domains: pain, stiffness, and physical function. We used the WOMAC function domain to evaluate physical ADLs. It consisted of 17 items: assessing difficulties in descending stairs, ascending stairs, rising from sitting, standing, bending to floor, walking on a flat surface, getting in/out of car/bus, going shopping, putting on socks/stockings, rising from bed, taking off socks/stockings, lying in bed, getting into/out of bath, sitting, getting on/off toilet, heavy domestic duties, and light domestic duties. Each item in the domain is graded on either a 5-point Likert scale (scores of 0–4) or a 100-mm visual analog scale [6, 7]. In the present study, we used the Likert scale (version LK 3.0). Items were rated from 0 to 4; 0, no difficulty; 1, mild difficulty; 2, moderate difficulty; 3, severe difficulty; 4, extreme difficulty. The domain score ranges from 0 to 68. Japanese versions of the WOMAC have been validated [8].

Certification of need of care in the LTCI system

The nationally uniform criteria for long-term care need certification was established objectively by the Japanese Government, and certification of need of care-level elderly is determined based on evaluation results by the Certification Committee for Long-term Care Need in municipalities in accordance with basic guidelines formulated by the Government. The process of eligibility for certification of need of care in the LTCI system was described in detail by Chen et al. [9]. An elderly person who requires help with ADLs or the caregiver contacts the municipal government to request official certification of care needs. After the application, a trained official visits the home to assess the current physical status of the elderly person, including presence or absence of muscle weakness or joint contracture of limbs, and difficulties in sitting-up, standing-up, maintaining sitting or standing position, transferring from one place to another, standing on one leg, walking, bathing, dressing, and other ADLs. Mental status, including dementia, also is assessed. These data are analyzed to calculate a standardized score for determination of the level of care needs (certified support, levels 1–2; or long-term care, levels 1–5). In addition, the primary physician of the applicant assesses physical and mental status, including information on diseases causing ADL disability and the extent of disabilities caused by them. Finally, the Certification Committee for Long-term Care Need reviews the data and determines the certification and its level.

Follow-up and definition of incident certified need of care

After the baseline ROAD survey, participants who were not certified as in need of care-level elderly at baseline were followed for incident certification of need of care in the LTCI system. Incident certified need of care was defined as the incident certified 7 levels, including requiring support (levels 1–2) and requiring long-term care (levels 1–5). Information on the presence or absence of certification of need of care and its date of occurrence were collected by the resident registration listings in three communities every year up to 2010, and were used for analyses in the present study.

Statistical analysis

All statistical analyses were performed using STATA statistical software (STATA, College Station, TX, USA). Differences in values of the parameters between the two groups were tested for significance using the unpaired Student's *t* test, the Mann–Whitney's *U* test, and Chi-square test. We used receiver operating characteristic (ROC) curve analysis to determine a cut-off value of the WOMAC function score for discriminating two distinct groups: an occurrence and a non-occurrence group of certified need of care. Cut-off values were determined that maximized the sum of sensitivity and specificity. Factors associated with the occurrence of certified need of care were determined using Cox proportional hazards regression analysis; hazard ratios (HRs) and 95 % confidence intervals (CIs) were determined after adjusting for region, age, sex, and BMI. Smoking habit and alcohol consumption were not included as confounders because they were not significantly associated with the incidence of certified need of care.

Results

Of the 1,773 participants who were not certified as in need of care-level elderly at baseline, information on

Table 1 Baseline characteristics of population at risk for the certified need of care in the LTCI system

	Men	Women
No. of subjects	699	1,074
Age (years)	75.6 (5.1)	75.2 (5.3)
Height (cm)	160.9 (6.0)	147.9 (6.0)[b]
Weight (kg)	59.4 (9.1)	50.0 (8.3)[b]
BMI (kg/m^2)	22.9 (2.9)	22.8 (3.4)
Smoking (%)	21.0	3.2[c]
Alcohol consumption, %	61.2	23.0[c]
WOMAC function domain		
Descending stairs, pts[a]	0 (0, 0, 1, 1)	0 (0, 0, 1, 2)[d]
Ascending stairs, pts[a]	0 (0, 0, 1, 1)	0 (0, 0, 1, 2)
Rising from sitting, pts[a]	0 (0, 0, 0, 1)	0 (0, 0, 1, 1)[d]
Standing, pts[a]	0 (0, 0, 0, 1)	0 (0, 0, 1, 1)[d]
Bending to floor, pts[a]	0 (0, 0, 0, 1)	0 (0, 0, 1, 1)
Walking on a flat surface, pts[a]	0 (0, 0, 0, 1)	0 (0, 0, 0, 1)
Getting in/out of car/bus, pts[a]	0 (0, 0, 0, 1)	0 (0, 0, 1, 1)[d]
Going shopping, pts[a]	0 (0, 0, 0, 1)	0 (0, 0, 0, 1)[d]
Putting on socks/stockings, pts[a]	0 (0, 0, 0, 1)	0 (0, 0, 0, 1)[d]
Rising from bed, pts[a]	0 (0, 0, 0, 1)	0 (0, 0, 0, 1)[d]
Taking off socks/stockings, pts[a]	0 (0, 0, 0, 1)	0 (0, 0, 0, 1)[d]
Lying in bed, pts[a]	0 (0, 0, 0, 0)	0 (0, 0, 0, 1)[d]
Getting into/out of bath, pts[a]	0 (0, 0, 0, 0)	0 (0, 0, 0, 1)[d]
Sitting, pts[a]	0 (0, 0, 0, 0)	0 (0, 0, 0, 0)[d]
Getting on/off toilet, pts[a]	0 (0, 0, 0, 1)	0 (0, 0, 1, 2)[d]
Heavy domestic duties, pts[a]	0 (0, 0, 0, 1)	0 (0, 0, 0, 1)[d]
Light domestic duties, pts[a]	0 (0, 0, 0, 1)	0 (0, 0, 0, 1)[d]
Total, pts[a]	1 (0, 0, 5, 12)	2 (0, 0, 8, 17)[d]

Except where indicated otherwise, values are mean (SD)

LTCI long-term care insurance system, *BMI* body mass index, *WOMAC* the Western Ontario and McMaster Universities Arthritis Index

[a] Median (10, 25, 75, and 90 percentile)

[b] $P < 0.05$ vs men by unpaired Student's *t* test

[c] $P < 0.05$ vs men by Chi-square test

[d] $P < 0.05$ vs men by Mann–Whitney *U* test

Table 2 Association of physical activities of daily living with the occurrence of certified need of care in the LTCI system

Physical activity	Overall population		Men		Women	
	HR (95 % CI)	*P* value	HR (95 % CI)	*P* value	HR (95 % CI)	*P* value
Descending stairs, pts	1.47 (1.26, 1.72)	<0.001	1.29 (0.96, 1.74)	0.089	1.56 (1.30, 1.87)	<0.001
Ascending stairs, pts	1.47 (1.25, 1.73)	<0.001	1.29 (0.93, 1.77)	0.123	1.55 (1.29, 1.86)	<0.001
Rising from sitting, pts	1.58 (1.34, 1.88)	<0.001	1.38 (0.95, 1.99)	0.092	1.67 (1.37, 2.03)	<0.001
Standing, pts	1.64 (1.41, 1.91)	<0.001	1.39 (1.02, 1.90)	0.037	1.73 (1.45, 2.06)	<0.001
Bending to floor, pts	1.57 (1.32, 1.85)	<0.001	1.61 (1.15, 2.27)	0.006	1.57 (1.29, 1.90)	<0.001
Walking on a flat surface, pts	1.57 (1.30, 1.90)	<0.001	1.25 (0.88, 1.77)	0.22	1.78 (1.41, 2.23)	<0.001
Getting in/out of car/bus, pts	1.76 (1.47, 2.10)	<0.001	1.60 (1.14, 2.26)	0.007	1.85 (1.50, 2.29)	<0.001
Going shopping, pts	1.72 (1.46, 2.03)	<0.001	1.55 (1.14, 2.11)	0.005	1.81 (1.48, 2.21)	<0.001
Putting on socks/stockings, pts	1.60 (1.33, 1.92)	<0.001	1.41 (0.98, 2.03)	0.065	1.71 (1.37, 2.12)	<0.001
Rising from bed, pts	1.68 (1.40, 2.03)	<0.001	1.41 (0.98, 2.02)	0.066	1.83 (1.47, 2.29)	<0.001
Taking off socks/stockings, pts	1.64 (1.37, 1.98)	<0.001	1.48 (1.01, 2.16)	0.046	1.72 (1.39, 2.13)	<0.001
Lying in bed, pts	1.82 (1.44, 2.30)	<0.001	1.96 (1.13, 3.40)	0.017	1.79 (1.38, 2.32)	<0.001
Getting into/out of bath, pts	1.71 (1.43, 2.04)	<0.001	1.64 (1.15, 2.33)	0.006	1.75 (1.43, 2.15)	<0.001
Sitting, pts	2.21 (1.73, 2.82)	<0.001	1.92 (1.14, 3.22)	0.014	2.32 (1.75, 3.06)	<0.001
Getting on/off toilet, pts	1.87 (1.52, 2.29)	<0.001	1.51 (1.00, 2.27)	0.05	2.09 (1.63, 2.68)	<0.001
Heavy domestic duties, pts	1.27 (1.09, 1.49)	0.003	1.20 (0.89, 1.62)	0.238	1.33 (1.10, 1.60)	0.003
Light domestic duties, pts	1.68 (1.41, 2.01)	<0.001	1.49 (1.07, 2.07)	0.019	1.80 (1.45, 2.24)	<0.001

Hazard ratios (HRs) and 95 % confidence intervals (CIs) were determined by Cox proportional hazards regression analysis after adjusting for age, sex, body mass index, and region in the overall population, and after adjusting for age, body mass index, and region in men and in women, respectively

LTCI long-term care insurance system

certification of need of care could be obtained in 1,760 (99.3 %) during the average 4.0-year follow-up. Fifty-four men and 115 women were certified as in need of care-level elderly in the national LTCI system, whereas, 1,591 remained uncertified during the follow-up period. The average period for the certification was 2.3 years. Among the above 54 men and 115 women, those who were certified as requiring long-term care level 1, 2, 3, 4, and 5 were 7, 9, 2, 4, 3 men, and 12, 17, 9, 4, 4 women, respectively. One hundred and twenty-six participants died and eight moved away. Incidence of certified need of care in the LTCI system was 2.3/100 person-years in the overall population, and 2.0/100 person-years in men and 2.5/100 person-years in women. Table 1 shows the baseline characteristics of the population at risk for occurrence of certified need of care in the LTCI system. The score of each item in the WOMAC function domain was significantly higher in women than in men in almost all items.

We then investigated association of each item in the WOMAC function domain with the occurrence of certified need of care in the LTCI system (Table 2). All 17 items in the WOMAC function domain were significantly associated with the occurrence of the certified need of care in the overall population and in women. In men, standing, bending to floor, getting in/out of car/bus, going shopping, taking off socks/stockings, lying in bed, getting into/out of bath, sitting, and light domestic duties were significantly associated with the occurrence of certified need of care, whereas other ADLs were not. In addition, the value of HR for each item in the association was higher in women than in men in 15 of 17 items.

Next we determined cut-off values of total score of the WOMAC function domain for discriminating two groups: an occurrence and a non-occurrence group of certified need of care using ROC curve analysis. The area under ROC curve was 0.70 in the overall population, 0.61 in men, and 0.74 in women (Fig. 1). The cut-off value of the WOMAC function score that maximized the sum of sensitivity and specificity was 6, 5, and 6 in the overall population, in men, and in women, respectively. In addition, the sensitivity/specificity was 57.3/75.0 % in the overall population, 45.7/75.0 % in men, and 64.4/72.6 % in women, respectively (Table 3). Furthermore, the cut-off value by which the sum was the second largest was 4 in the overall population, 4 in men, and 4 in women, and the sensitivity/specificity was 65.3/66.7 % in the overall population, 50.0/70.0 % in men, and 72.1/64.5 % in women, respectively (Table 3).

Because ROC curve analysis is a univariate analysis, we performed multivariate Cox hazards regression analysis to determine the cut-off value of the WOMAC function score for best discriminating between an occurrence and a non-

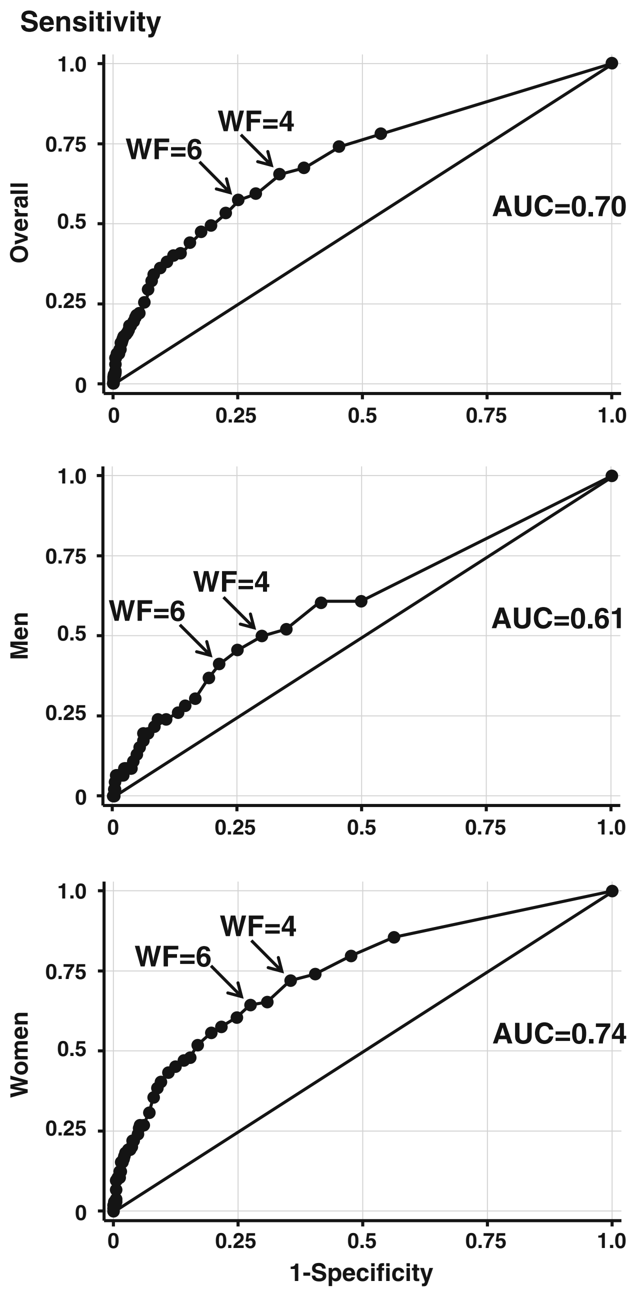

Fig. 1 Receiver operating characteristic (ROC) curve analysis for discriminating the occurrence group of certified need of care in the overall population, in men, and in women. *AUC* area under ROC curve, *WF* WOMAC (Western Ontario and McMaster Universities Osteoarthritis Index) function score

occurrence group of certified need of care after adjusting for age, sex, BMI, and region (Table 4). The group with WOMAC function score $\geq$4 was significantly associated with the occurrence of certified need of care compared with the group with the score <4 with the highest HR in the overall population [HR 2.54, 95 % CI (1.76–3.67)] and in women [HR 3.13, 95 % CI (1.95–5.02)]. In men, the group with WOMAC function score $\geq$5 was significantly

Table 3 Sensitivity and specificity of the occurrence of certified need of care determined by the cut-off point of the WOMAC function score

Cut-off point	Overall population			Men			Women		
	Sensitivity (%)	Specificity (%)	Sensitivity + specificity (%)	Sensitivity (%)	Specificity (%)	Sensitivity + specificity (%)	Sensitivity (%)	Specificity (%)	Sensitivity + specificity (%)
WF = 4pts	65.3	66.7	132.0	50.0	70.0	120.0	72.1	64.5	136.6
WF = 5pts	59.3	71.4	130.7	45.7	75.0	120.7	65.4	69.2	134.6
WF = 6pts	57.3	75.0	132.3	41.3	78.6	119.9	64.4	72.6	137.0

WOMAC the Western Ontario and McMaster Universities Arthritis Index, *WF* WOMAC function score

Table 4 Association of groups divided by the WOMAC function score with the occurrence of certified need of care in the LTCI system

	Overall population		Men		Women	
	HR (95 % CI)	*P* value	HR (95 % CI)	*P* value	HR (95 % CI)	*P* value
WF ≥ 4 pts vs WF < 4 pts	2.54 (1.76, 3.67)	<0.001	1.85 (1.01, 3.39)	0.045	3.13 (1.95, 5.02)	<0.001
WF ≥ 5 pts vs WF < 5 pts	2.35 (1.64, 3.36)	<0.001	1.88 (1.03, 3.43)	0.040	2.71 (1.73, 4.27)	<0.001
WF ≥ 6 pts vs WF < 6 pts	2.50 (1.75, 3.58)	<0.001	1.84 (1.00, 3.39)	0.051	3.03 (1.93, 4.76)	<0.001

Hazard ratios (HRs) and 95 % confidence intervals (CIs) were determined by Cox proportional hazards regression analysis after adjusting for age, sex, body mass index, and region in the overall population, and after adjusting for age, body mass index, and region in men and in women, respectively

WOMAC the Western Ontario and McMaster Universities Arthritis Index, *LTCI* long-term care insurance system, *WF* WOMAC function score

Table 5 Association of the WOMAC function score with the occurrence of different certified need of care levels in the LTCI system

Outcome variable	Overall population		Men		Women	
	HR (95 % CI)	*P* value	HR (95 % CI)	*P* value	HR (95 % CI)	*P* value
RSL1–2 and RCL 1–5	1.05 (1.03, 1.06)	<0.001	1.03 (1.01, 1.06)	0.008	1.05 (1.04, 1.07)	<0.001
RCL 1–5	1.05 (1.03, 1.07)	<0.001	1.04 (1.00, 1.07)	0.046	1.06 (1.03, 1.08)	<0.001
RCL 2–5	1.06 (1.04, 1.08)	<0.001	1.04 (1.01, 1.08)	0.015	1.06 (1.04, 1.09)	<0.001
RCL 3–5	1.05 (1.03, 1.08)	<0.001	1.05 (0.99, 1.10)	0.099	1.06 (1.02, 1.09)	0.001
RCL 4–5	1.04 (1.00, 1.08)	0.048	1.02 (0.95, 1.10)	0.501	1.05 (1.00, 1.10)	0.057
RCL 5	1.01 (0.93, 1.09)	0.830	0.99 (0.82, 1.20)	0.945	1.01 (0.93, 1.11)	0.780

Hazard ratios (HRs) and 95 % confidence intervals (CIs) were determined by Cox proportional hazards regression analysis after adjusting for age, sex, body mass index, and region in the overall population, and after adjusting for age, body mass index, and region in men and in women, respectively

WOMAC the Western Ontario and McMaster Universities Arthritis Index, *LTCI* long-term care insurance system, *RSL* requiring support level, *RCL* requiring long-term care level

associated with the occurrence of certified need of care compared with the group with a score of <5 with the highest HR [HR 1.88, 95 % CI (1.03–3.43)].

Furthermore, we examined association of the WOMAC function domain with the occurrence of different certified need of care levels in the LTCI system (Table 5). When the outcome variable of the occurrence was defined as requiring support level (RSL) 1–2 and requiring long-term care level (RCL) 1–5, RCL 1–5, and RCL 2–5, there were significant associations in the overall population, in men, and in women, respectively. When the outcome variable of the occurrence was defined as RCL 3–5, there were significant associations in the overall population and in women. When the outcome variable of the occurrence was defined as RCL 4–5, there was significant association in the overall population.

Discussion

The present study determined association of physical ADLs with the incidence of certified need of care in the national LTCI system in elderly participants of Japanese population-based cohorts. All 17 items in the WOMAC function domain were significantly associated with the occurrence of certified need of care in the overall population. ROC curve analysis showed that cut-off values of the WOMAC function score of around 4–6 maximized the sum of sensitivity and specificity of the occurrence of certified need of care. Furthermore, multivariate Cox hazards regression analysis revealed that the group with WOMAC function score ≥4 was significantly associated with the occurrence of certified need of care with the highest HR after adjusting for confounders in the overall population and in women, while the group with WOMAC function score ≥5 was significantly associated with the highest HR in men.

In the present study, we could not obtain information on causes of certified need of care in the LTCI system. Therefore, we could not analyze the direct association of each causing condition with the WOMAC function domain. The Government of Japan reported that the top five leading causes of certified need of care were cerebral stroke (21.5 %), dementia (15.3 %), asthenia as a result of older age (13.7 %), joint disease (10.9 %) and fall-related fracture (10.2 %), comprising 71.6 % of all causes in 2010 [10]. Based on these data, most of the causes of incident certification in the present study are inferred to be among the top five leading conditions. Although we could not know the exact percentage of each causing condition, joint disease and fall-related fracture are inferred to represent approximately 20 % in total causes of incident certification in the present study, and cerebral stroke, dementia, and asthenia as a result of older age are inferred to represent approximately 50 % in total causes of incident certification.

The Government of Japan also reported that the percentage of joint disease and fall-related fracture was 16.7 % for the cause of RCL 1–5 [10]. Furthermore, it was 17.6, 19.8, 14.8, 17.4, and 9.8 % for the cause of RCL 1, 2, 3, 4, and 5, respectively [10]. Although we could not know the exact percentage of joint disease and fall-related fracture for the cause of each RCL in the present study, the percentage for the cause of RCL 1–4 is inferred to be approximately 15 % or more based on the data of the Government of Japan, which may be the reason why the WOMAC domain was significantly associated with the occurrence of certified need of care including RCLs 1–4 in the overall population.

The WOMAC physical function domain assesses difficulties in ADLs, including going up/down stairs, getting in/out of a car and bath, shopping, and household duties. Therefore, results of the present study indicate that the severity of physical dysfunction in ADLs predicts subsequent deterioration in ADLs, leading to the occurrence of certified need of care. Previous studies reported that low physical function was a predictor of subsequent ADL disability in the elderly [11, 12]. Although no previous studies have investigated the association of physical ADLs with the incidence of certified need of care in the national LTCI system in large-scale population-based cohorts, those previous findings are consistent with the present results in that low physical activity predicted subsequent deterioration in ADLs.

All 17 items in the WOMAC domain were significantly associated with the occurrence of certified need of care in women. On the other hand, 9 of 17 items were significantly associated with the occurrence of certified need of care in men. In addition, the HR for each item in the association was higher in women than in men for 15 of 17 items. The sex difference identified in this association may be due to the difference in the prevalence of knee osteoarthritis between the sexes. Muraki et al. [13] reported that prevalence of radiographic knee osteoarthritis determined by the Kellgren–Lawrence grade $\geq$2 was 47.0 % in men and 70.2 % in women, respectively, in subjects aged 60 years and older in Japanese population-based cohorts. Therefore, women are more likely than men to be affected by knee osteoarthritis and have difficulties in physical function of the lower extremities, leading to higher scores on the WOMAC function scale. Another reason for the sex differences may be the weaker muscle strength in women; muscle strength in men is higher than that in women in all decades of life [14], which may obscure the association in men, as muscle strength has been reported to be inversely associated with the WOMAC domains [15].

Functional declines in locomotive organs including physical ADLs usually progress slowly and gradually. As such, it may be difficult for people to recognize this decline in their daily life. Therefore, it is of particular importance to raise awareness of the growing risk caused by such disorders, and to take action to improve and maintain the health of the locomotive organs. The Japanese Orthopaedic Association proposed the concept of “locomotive syndrome” in 2007 for the promotion of preventive healthcare of the locomotive organs [16–18]. Locomotive syndrome refers to conditions under which the elderly have been receiving support or long-term care, or high-risk conditions under which they may soon require support or long-term care, that are caused by musculoskeletal disorders [16–18]. Population approaches, including promotion of the concept of locomotive syndrome to both younger and older generations, are important, in addition to high-risk approaches, including identifying those at risk for certified need of care and practicing intervention programs to reduce the risk of certified need of care.

Because the WOMAC function scale is a self-assessment questionnaire that is easy to conduct and evaluate, it can be used to screen elderly persons at high risk of certified need of care in the LTCI system. Multivariate Cox hazards regression analysis showed that a WOMAC function score of 5 in men and 4 in women best discriminated between the occurrence and the non-occurrence group of certified need of care in this study population. Elderly men with a WOMAC function score $\geq$5 had a 1.88-fold higher risk of occurrence of certified need of care compared with elderly men with a score $<$5. Elderly women with a WOMAC function score $\geq$4 had a 3.13-fold higher risk of occurrence of certified need of care compared with elderly women with a score $<$4. Elderly persons screened by these cut-off values should receive early intervention for the prevention of subsequent deterioration in ADLs that could lead to certified need of care. Further studies, along with the accumulation of epidemiologic evidence, are necessary to develop intervention programs that are safe and effective for elderly subjects who are at high risk of certified need of care.

There are some limitations in the present study. First, we could not obtain information on causes of certified need of care in the LTCI system. Therefore, we could not analyze the direct association of each causing condition with measured factors, and could not determine the risk factors for occurrence of certified need of care with respect to each causing condition. The Japanese government reported that the top five leading causes of certified need of care were cerebral stroke, dementia, asthenia, osteoarthritis, and fall-related fracture, comprising 71.6 % of all causes in 2010 [10]. Based on these data, most of the causes of incident certification in the present study are inferred to be among the top five leading conditions. Additional studies are necessary to identify those direct associations. Second, participants at baseline in the present study were those who could walk to the survey site and could understand and sign an informed consent form. Since those who could not were not included in the analyses, the study participants do not truly represent the general population due to health bias, which should be taken into consideration when generalizing the results of the present study.

In conclusion, the present study determined association of physical ADLs with the occurrence of certified need of care in the LTCI system in elderly participants of Japanese population-based cohorts. The severity of physical dysfunction is a predictor of the occurrence of certified need of care. Further studies are necessary to develop intervention programs that are safe and effective for elderly individuals who are at high risk of certified need of care.

Acknowledgments This study was supported by Grants-in-Aid for Scientific Research (S19109007, B20390182, B23390172, B23390356, and B23390357) from the Japanese Ministry of Education, Culture, Sports, Science and Technology; H17-Men-eki-009, H18-Choujyu-037, H20-Choujyu-009, H21-Chouju-Wakate-011, H22-Chouju-Wakate-007, H23-Chouju-002, and H25-Chouju-007 from the Ministry of Health, Labour and Welfare; and Research Aid from the Japanese Orthopaedic Association (JOA-Subsidized Science Project Research 2006-1 and 2010-2).

Conflict of interest There are no conflicts of interest.

References

1. National Institute of Population and Society Research. Population projections for Japan (January 2012): 2011 to 2060. http://www.ipss.go.jp/site-ad/index_english/esuikei/gh2401e.asp.
2. Ministry of Health, Labour and Welfare. Long-term care, health and welfare services for the elderly. http://www.mhlw.go.jp/english/policy/care-welfare/care-welfare-elderly/index.html.
3. Yoshimura N, Muraki S, Oka H, Kawaguchi H, Nakamura K, Akune T. Cohort profile: research on osteoarthritis/osteoporosis against disability study. Int J Epidemiol. 2010;39:988–95.
4. Yoshimura N, Muraki S, Oka H, Mabuchi A, En-Yo Y, Yoshida M, Saika A, Yoshida H, Suzuki T, Yamamoto S, Ishibashi H, Kawaguchi H, Nakamura K, Akune T. Prevalence of knee osteoarthritis, lumbar spondylosis, and osteoporosis in Japanese men and women: the research on osteoarthritis/osteoporosis against disability study. J Bone Miner Metab. 2009;27:620–8.
5. Shimada H, Lord SR, Yoshida H, Kim H, Suzuki T. Predictors of cessation of regular leisure-time physical activity in community-dwelling elderly people. Gerontology. 2007;53:293–7.
6. Barr S, Bellamy N, Buchanan WW, Chalmers A, Ford PM, Kean WF, Kraag GR, Gerecz-Simon E, Campbell J. A comparative study of signal versus aggregate methods of outcome measurement based on the WOMAC Osteoarthritis Index. Western Ontario and McMaster Universities Osteoarthritis Index. J Rheumatol. 1994;21:2106–12.
7. Bellamy N, Buchanan WW, Goldsmith CH, Campbell J, Stitt LW. Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. J Rheumatol. 1988;15:1833–40.
8. Hashimoto H, Hanyu T, Sledge CB, Lingard EA. Validation of a Japanese patient-derived outcome scale for assessing total knee arthroplasty: comparison with Western Ontario and McMaster Universities osteoarthritis index (WOMAC). J Orthop Sci. 2003;8:288–93.
9. Chen W, Fukutomi E, Wada T, Ishimoto Y, Kimura Y, Kasahara Y, Sakamoto R, Okumiya K, Matsubayashi K. Comprehensive geriatric functional analysis of elderly populations in four categories of the long-term care insurance system in a rural, depopulated and aging town in Japan. Geriatr Gerontol Int. 2013;13:63–9.
10. Ministry of Health, Labour and Welfare. The outline of the results of National Livelihood Survey. 2010. http://www.mhlw.go.jp/toukei/saikin/hw/k-tyosa/k-tyosa10/4-2.html.
11. Guralnik JM, Ferrucci L, Simonsick EM, Salive ME, Wallace RB. Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. N Engl J Med. 1995;332:556–61.
12. Vermeulen J, Neyens JC, van Rossum E, Spreeuwenberg MD, de Witte LP. Predicting ADL disability in community-dwelling elderly people using physical frailty indicators: a systematic review. BMC Geriatr. 2011;11:33.
13. Muraki S, Oka H, Akune T, Mabuchi A, En-yo Y, Yoshida M, Saika A, Suzuki T, Yoshida H, Ishibashi H, Yamamoto S, Nakamura K, Kawaguchi H, Yoshimura N. Prevalence of radiographic knee osteoarthritis and its association with knee pain in the elderly of Japanese population-based cohorts: the ROAD study. Osteoarthr Cartil. 2009;17:1137–43.
14. Sinaki M, Nwaogwugwu NC, Phillips BE, Mokri MP. Effect of gender, age, and anthropometry on axial and appendicular muscle strength. Am J Phys Med Rehabil. 2001;80:330–8.
15. Muraki S, Akune T, Oka H, En-yo Y, Yoshida M, Saika A, Suzuki T, Yoshida H, Ishibashi H, Tokimura F, Yamamoto S, Nakamura K, Kawaguchi H, Yoshimura N. Association of radiographic and symptomatic knee osteoarthritis with health-related quality of life in a population-based cohort study in Japan: the ROAD study. Osteoarthr Cartil. 2010;18:1227–34.
16. Nakamura K. A "super-aged" society and the "locomotive syndrome". J Orthop Sci. 2008;13:1–2.
17. Nakamura K. Locomotive syndrome: disability-free life expectancy and locomotive organ health in a "super-aged" society. J Orthop Sci. 2009;14:1–2.
18. Nakamura K. The concept and treatment of locomotive syndrome: its acceptance and spread in Japan. J Orthop Sci. 2011;16:489–91.

Osteoporos Int (2014) 25:1081–1088
DOI 10.1007/s00198-013-2550-z

ORIGINAL ARTICLE

Exercise habits during middle age are associated with lower prevalence of sarcopenia: the ROAD study

T. Akune · S. Muraki · H. Oka · S. Tanaka · H. Kawaguchi · K. Nakamura · N. Yoshimura

Received: 8 July 2013 / Accepted: 3 October 2013 / Published online: 22 October 2013

Abstract
Summary The present cross-sectional study investigated the prevalence of sarcopenia and clarified its associated factors in 1,000 elderly participants of Japanese population-based cohorts. Exercise habit in middle age was associated with low prevalence of sarcopenia in older age, suggesting that it is a protective factor against sarcopenia in older age.
Introduction The present study investigated the prevalence of sarcopenia using the European Working Group on Sarcopenia in Older People (EWGSOP) definition, and clarified the association of sarcopenia with physical performance in the elderly participants of Japanese population-based cohorts of the Research on Osteoarthritis/osteoporosis Against Disability (ROAD) study.
Methods We enrolled 1,000 participants (aged ≥65 years) from the second visit of the ROAD study who had completed assessment of handgrip strength, gait speed, and skeletal muscle mass measured by bioimpedance analysis. Presence of sarcopenia was determined according to the EWGSOP algorithm. Information collected included exercise habits in middle age.
Results Prevalence of sarcopenia was 13.8 % in men and 12.4 % in women, and tended to be significantly higher according to increasing age in both sexes. Factors associated with sarcopenia, as determined by logistic regression analysis, were chair stand time (odds ratio [OR], 1.09; 95 % confidence interval [CI], 1.04–1.14), one-leg standing time (OR, 0.97; 95 % CI, 0.96–0.99), and exercise habit in middle age (OR, 0.53; 95 % CI, 0.31–0.90). Exercise habit in middle age was associated with low prevalence of sarcopenia in older age. Furthermore, linear regression analysis revealed that exercise habits in middle age were significantly associated with grip strength ($P < .001$), gait speed ($P < .001$), and one-leg standing time ($P = .005$) in older age.
Conclusions This cross-sectional study suggests that exercise habit in middle age is a protective factor against sarcopenia in older age and effective in maintaining muscle strength and physical performance in older age.

Keywords Elderly · Epidemiology · Exercise · Physical performance · Sarcopenia

T. Akune (✉) · S. Muraki
Department of Clinical Motor System Medicine, 22nd Century Medical and Research Center, Graduate School of Medicine, University of Tokyo, Hongo 7-3-1 Bunkyo-ku, Tokyo 113-8655, Japan
e-mail: akune-ort@h.u-tokyo.ac.jp

H. Oka · N. Yoshimura
Department of Joint Disease Research, 22nd Century Medical and Research Center, Graduate School of Medicine, University of Tokyo, Tokyo, Japan

S. Tanaka · H. Kawaguchi
Department of Sensory and Motor System Medicine, Graduate School of Medicine, University of Tokyo, Tokyo, Japan

K. Nakamura
National Rehabilitation Center for Persons with Disabilities, Saitama, Japan

Introduction

Sarcopenia is characterized by generalized loss of skeletal muscle mass and muscle strength and/or function in the elderly, causing multiple adverse health outcomes, including physical disability, poor quality of life, and death [1–6]. Although cross-sectional studies have investigated prevalence of sarcopenia [7–13], epidemiologic evidence using population-based samples is insufficient despite the urgent need for strategies to prevent and treat this condition.

Japan is a super-aged society, and the proportion of the aged population is increasing. The percentage of individuals aged ≥65 years was 23 % in 2010 and is expected to reach 30.1 % in 2024 and 39 % in 2051 [14]. The government of Japan reported that musculoskeletal disorders were present in 22.9 % of the entire population of those who were certified as requiring assistance or long-term care elderly in 2010 and were ranked first among its causes, together with joint diseases, falls, fractures, and spinal cord disorders [15]. For preventing and treating musculoskeletal disorders, there is an urgent need to develop and establish a prevention strategy and treatment programs that are effective in reducing the risk of disability among the elderly, which leads to requirement of assistance or long-term care. Although sarcopenia is a common musculoskeletal disease in the elderly, it is not clearly categorized [15]. There appears to be insufficient recognition of sarcopenia in daily clinical practice and society, leading to the disease being undiagnosed and untreated. One of the reasons may be the lack of a broadly accepted definition of sarcopenia until the European Working Group on Sarcopenia in Older People (EWGSOP) developed a practical clinical definition and consensus diagnostic criteria for this disease in 2010 [4]. There is a growing consensus that sarcopenia should not be defined merely on the basis of muscle mass but also with regard to muscle strength and function [4]. However, few epidemiologic studies have been based on the EWGSOP definition of sarcopenia using population-based samples, and no epidemiologic study has investigated the relationship between exercise habits in middle age and sarcopenia in older age.

The Research on Osteoarthritis/osteoporosis Against Disability (ROAD) study is a prospective cohort study aimed at elucidating the environmental and genetic background of musculoskeletal diseases [16, 17]. The present study investigated the prevalence of sarcopenia using the EWGSOP definition, and clarified the association of sarcopenia with exercise habits in middle age and physical performance in the elderly participants of Japanese population-based cohorts of the ROAD study.

Methods

Participants

From 2005–2007, we began a large-scale population-based cohort study entitled Research on Osteoarthritis/osteoporosis Against Disability consisting of 3,040 participants in three regions (baseline study) [16, 17]. The ROAD study is a prospective cohort study with the aim of elucidating the environmental and genetic backgrounds of musculoskeletal diseases. It is designed to examine the extent to which risk factors for these diseases are related to clinical features of the diseases, laboratory and radiographic findings, bone mass, bone geometry, lifestyle, nutritional factors, anthropometric and neuromuscular measures, and fall propensity. It also aims to determine how these diseases affect activities of daily living and quality of life of Japanese men and women. The subjects were residents of any one of three communities: an urban region in Itabashi, Tokyo; a mountainous region in Hidakagawa, Wakayama; and a coastal region in Taiji, Wakayama. The inclusion criteria were as follows: ability to (1) walk to the clinic where the survey was performed, (2) provide self-reported data, and (3) understand and sign an informed consent form. Participants from the urban region were aged ≥60 years and were recruited from those enrolled in a randomly selected cohort study from the previously established Itabashi Ward residential registration database [18]. Invitation letters were distributed only to inhabitants whose names were listed on this database. Participants from Hidakagawa and Taiji were aged ≥40 years and were recruited from residential registration listings. Residents aged <60 years from Itabashi and <40 years from Hidakagawa and Taiji who were interested in participating in the study were also invited. A total of 99.8, 84.3, and 54.7 % of the participants were aged ≥60 years in Itabashi, Hidakagawa, and Taiji, respectively. The response rates in the groups aged ≥60 years were 75.6 % in Itabashi, 68.4 % in Hidakagawa, and 29.3 % in Taiji. Two-thirds of the 3, 040 participants in the baseline survey were women, and their mean age was 1 year less than that of the male participants. No significant difference was observed in body mass index (BMI) between the sexes.

After the baseline study, a second survey was performed in the same communities from 2008 to 2010, in which 2,674 inhabitants (892 men, 1,782 women) aged 21–97 years participated (second visit) [19]. Invitation letters were distributed to the inhabitants whose names were listed on the baseline database of the ROAD study. In addition to the former participants, inhabitants aged ≥60 years from Itabashi and those aged ≥40 years from Hidakagawa and Taiji who were willing to participate in the ROAD survey performed in 2008–2010 were also included in the second visit. In addition, residents aged <60 years from Itabashi and <40 years from Hidakagawa and Taiji who were interested in participating in the study were invited to be examined as well at the baseline. The inclusion criteria were as follows: ability to (1) walk to the clinic where the survey was performed, (2) provide self-reported data, and (3) understand and sign an informed consent form. No other exclusion criteria were used. Thus, 2,674 residents (892 men and 1,782 women) aged 21–97 years participated in the second visit. Of the 2,674 participants, 1, 846 individuals aged ≥65 years visited the clinic and underwent an examination at the survey site located in Hidakagawa (504 individuals), Taiji (391 individuals), the University of Tokyo Hospital (132 individuals), or Tokyo Metropolitan Geriatric Hospital (819 individuals). For participants from Itabashi, the survey site was randomly assigned to either the University of Tokyo Hospital or Tokyo

Metropolitan Geriatric Hospital. Since gait speed was not measured at Tokyo Metropolitan Geriatric Hospital, 819 individuals who visited this hospital were removed from the present study. Of 1,846 participants, the remaining 1,019 individuals aged ≥65 years who visited the survey site located in Hidakagawa, Taiji, or at the University of Tokyo Hospital and underwent an examination including gait speed assessment were recruited for the present study. Of the 1,019 individuals, 19 were removed because 1 did not undergo handgrip strength measurement and 18 did not undergo skeletal muscle mass measurement. For the present study, we enrolled 1,000 participants (349 men and 651 women aged ≥65 years) from the second visit who completed assessment of handgrip strength, gait speed, and skeletal muscle mass. The mean age of the participants was 75.7 (SD, 5.9) years in men and 74.4 (SD, 6.1) years in women. All participants provided written informed consent, and the study was conducted with approval from the Ethics Committee of the University of Tokyo.

Participants completed an interviewer-administered questionnaire comprising 400 items regarding lifestyle information such as smoking habits, alcohol consumption, and physical activity. An interviewer asked the following question regarding past physical activity: "During the time you were aged 25–50 years, did you ever practice sports or physical exercise sufficient to produce sweating or shortness of breath?" Possible responses were as follows: never, occasionally, <2 hours per week, and ≥2 hours per week. Those who answered "occasionally, <2 hours per week, or ≥2 hours per week" were defined as having exercise habits in middle age. The following question was asked regarding current physical activity: "Do you practice walking more than 30 minutes every day?" Those who answered "yes" were defined as having a current walking habit.

Anthropometric and physical performance measurements

Anthropometric measurements, including height and weight, were obtained, and body mass index (weight [kg]/height [m^2]) was estimated based on the measured height and weight. Grip strength was measured on the right and left sides using a TOEI LIGHT handgrip dynamometer (TOEI LIGHT CO. LTD, Saitama, Japan), and the highest measurement was used to characterize maximum muscle strength. Subjects were defined as having low grip strength if grip strength was <30 kg in men and <20 kg in women, as reported by Lauretani and colleagues [20].

Skeletal muscle mass was measured by bioimpedance analysis [21–25] using the Body Composition Analyzer MC-190 (Tanita Corp., Tokyo, Japan). The protocol was described by Tanimoto and colleagues [10, 12], and the method has been validated [26]. Appendicular skeletal muscle mass (ASM) was derived as the sum of the muscle mass of the arms and the legs. Absolute ASM was converted to an appendicular muscle mass index (SMI) by dividing by height in meters squared (kg/m^2). Subjects were defined as having low skeletal muscle mass if the SMI was <2 SDs of the young adult mean. We used an SMI of <7.0 kg/m^2 in men and <5.8 kg/m^2 in women as cut-off points for low skeletal muscle mass based on the reference data of SMI measured by the MC-190 in 1,719 healthy young Japanese volunteers aged 18–39 years [10].

To measure physical performance, the time taken to walk 6 m at normal walking speed in a hallway was recorded, and usual gait speed was calculated. Subjects were defined as having low gait speed if usual gait speed was ≤0.8 m/s. The time taken for five consecutive chair rises without the use of hands was also recorded. Timing began with the command "Go" and ended when the buttocks contacted the chair on the fifth landing. One-leg standing time with eyes open was measured on both sides, and the best measurement was used. Participants were asked to stand on one leg while continuing to elevate their contralateral limb. Timing commenced when the participant assumed the correct posture and ended when any body part touched a supporting surface.

Statistical analysis

All statistical analyses were performed using STATA statistical software (STATA, College Station, TX). Differences in the values of the parameters between two groups were tested for significance using the nonpaired Student's t test and chi-square test. Trends in values were tested using the Jonckheere-Terpstra trend test. Factors associated with sarcopenia were determined using multivariate logistic regression analysis with sarcopenia as the dependent variable; the odds ratio (OR) and 95 % confidence interval were determined after adjusting for age, sex, and BMI. Factors associated with exercise habits in middle age were determined using multivariate linear regression analysis with exercise habits in middle age as the independent variable; the regression coefficient and 95 % CI were determined after adjusting for age, sex, and BMI.

Results

Table 1 shows the characteristics of the participants according to EWGSOP sarcopenia status. Age was significantly greater, while BMI, ASM, and SMI were significantly lesser in those with sarcopenia than in those without sarcopenia in both men and women. In physical performance, chair stand time was significantly greater and one-leg standing time was significantly lesser in those with sarcopenia than in those without sarcopenia in both men and women. The percentage of individuals with exercise habits in middle age was significantly lower in those with sarcopenia than in those without sarcopenia in both men and women.

Table 1 Characteristics of participants according to EWGSOP sarcopenia status

	Men		Women	
	No sarcopenia	Sarcopenia	No sarcopenia	Sarcopenia
No. of subjects	301	48	570	81
Age, years	75.1 (5.8)	79.9 (5.2)*	73.5 (5.6)	80.8 (5.8)*
Height, cm	161.9 (6.0)	158.5 (5.8)*	148.9 (6.4)	145.6 (6.6)*
Weight, kg	61.2 (9.5)	52.9 (6.5)*	52.4 (8.4)	42.6 (6.3)*
BMI, kg/m^2	23.3 (3.0)	21.0 (2.0)*	23.6 (3.3)	20.0 (2.3)*
ASM, kg	19.8 (3.0)	16.0 (1.7)*	13.8 (1.8)	11.4 (1.2)*
SMI, kg/m^2	7.54 (0.90)	6.36 (0.47)*	6.22 (0.66)	5.35 (0.30)*
Grip strength, kg	36.9 (6.8)	28.0 (4.0)*	23.9 (4.6)	16.8 (3.4)*
Usual gait speed, m/s	1.11 (0.25)	0.85 (0.27)*	1.06 (0.28)	0.82 (0.22)*
Chair stand time, s	9.6 (3.7)	11.9 (4.2)*	9.9 (4.2)	13.4 (5.9)*
One-leg standing time, median (IQR), s	31.0 (10.0–60.0)	8.0 (4.0–16.0)*	26.0 (8.0–60.0)	11.0 (5.0–23.0)*
Smoking, %	15.6	16.7	2.3	6.2
Alcohol consumption, %	58.8	45.8	14.7	18.8
Current walking habits, %	56.5	45.0	55.1	56.5
Exercise habits in middle age, %	69.9	46.2†	43.3	26.1†

Except where indicated otherwise, values are mean (SD)

ASM appendicular skeletal muscle mass, *BMI* body mass index, *EWGSOP* European Working Group on Sarcopenia in Older People, *IQR* interquartile range, *SMI* skeletal muscle mass index

*$P<.001$ vs. no sarcopenia in the same sex group by unpaired Student's t test; †$P<.01$ vs. no sarcopenia in the same sex group by chi-square test

Figure 1 shows sex- and age-wise distributions of prevalence of sarcopenia (Fig. 1a), low SMI (Fig. 1b), low grip strength (Fig. 1c), and low gait speed (Fig. 1d). The total prevalence of sarcopenia was 13.8 % in men and 12.4 % in women. Prevalence of sarcopenia (number of cases/subjects) in the age strata of 65–69, 70–74, 75–79, 80–84, and ≥85 years was 1.6 % (1/63), 5.7 % (5/88), 17.8 % (19/107), 23.2 % (16/69), and 31.8 % (7/22) in men and 0.6 % (1/163), 5.5 % (10/182), 13.8 % (22/160), 22.9 % (25/109), and 62.2 % (23/37) in women. Prevalence of sarcopenia tended to be significantly higher according to increasing age ($P<.001$ for trend) in both men and women. Prevalence of low grip strength and low gait speed also tended to be significantly higher according to increasing age ($P<.001$ for trend) in both men and women. However, the increasing tendency of prevalence of low SMI ($P<.001$ for trend) was milder compared with that of sarcopenia, low grip strength, and low gait speed.

Then, we determined the factors associated with sarcopenia by logistic regression analysis; the upper part of Table 2 shows the results using sarcopenia as the dependent variable. In the overall population, age (OR, 1.20; 95 % CI, 1.15–1.24) and BMI (OR, 0.68; 95 % CI, 0.63–0.75) were significantly associated with sarcopenia, whereas sex was not. In physical performance, chair stand time (OR, 1.09; 95 % CI, 1.04–1.14) and one-leg standing time (OR, 0.94; 95 % CI, 0.96–0.99) were significantly associated with sarcopenia in the overall population after adjusting for age, sex, and BMI. Current walking habit (OR, 0.69; 95 % CI, 0.42–1.12) was not significantly associated with sarcopenia. However, exercise habit in middle age (OR, 0.53; 95 % CI, 0.31–0.90) was associated with sarcopenia in the overall population after adjusting for age, sex, and BMI, indicating that exercise habit in middle age was significantly associated with low prevalence of sarcopenia in older age. The significance of the association did not change when current walking habit was added as an explanatory variable in this logistic regression model (OR, 0.53; 95 % CI, 0.32–0.90). In addition, we investigated the association of each category—occasionally, <2 h per week, and ≥2 h per week—with sarcopenia using "never" as a reference, in addition to the association of the presence of exercise habits in middle age with sarcopenia. The associated ORs for the three categories were comparable, but they did not reach significance level (occasionally: OR, 0.63; 95 % CI, 0.34–1.17; <2 h per week: OR, 0.30; 95 % CI, 0.09–1.01; ≥2 h per week: OR, 0.49; 95 % CI, 0.22–1.09).

The lower part of Table 2 shows the results of linear regression analysis using SMI, grip strength, gait speed, chair stand time, or one-leg standing time as the dependent variable and exercise habit in middle age as the independent variable. Exercise habit in middle age was significantly associated with grip strength in older age ($P<.001$), gait speed in older age ($P<.001$), and one-leg standing time in older age ($P=.005$) after adjusting for age, sex, and BMI in the overall population. We conducted the same analyses in men and women separately (Tables 3 and 4) and found results similar to those in the overall population. Some sex differences were observed in the present results. Exercise habit in middle age was significantly associated with grip strength and gait speed in older age in both men and women, whereas it was significantly associated with chair stand time and one-leg standing time only in men; however, the sample size of men was smaller than that of women. In the overall population, exercise habit in middle age was not associated with chair stand time.

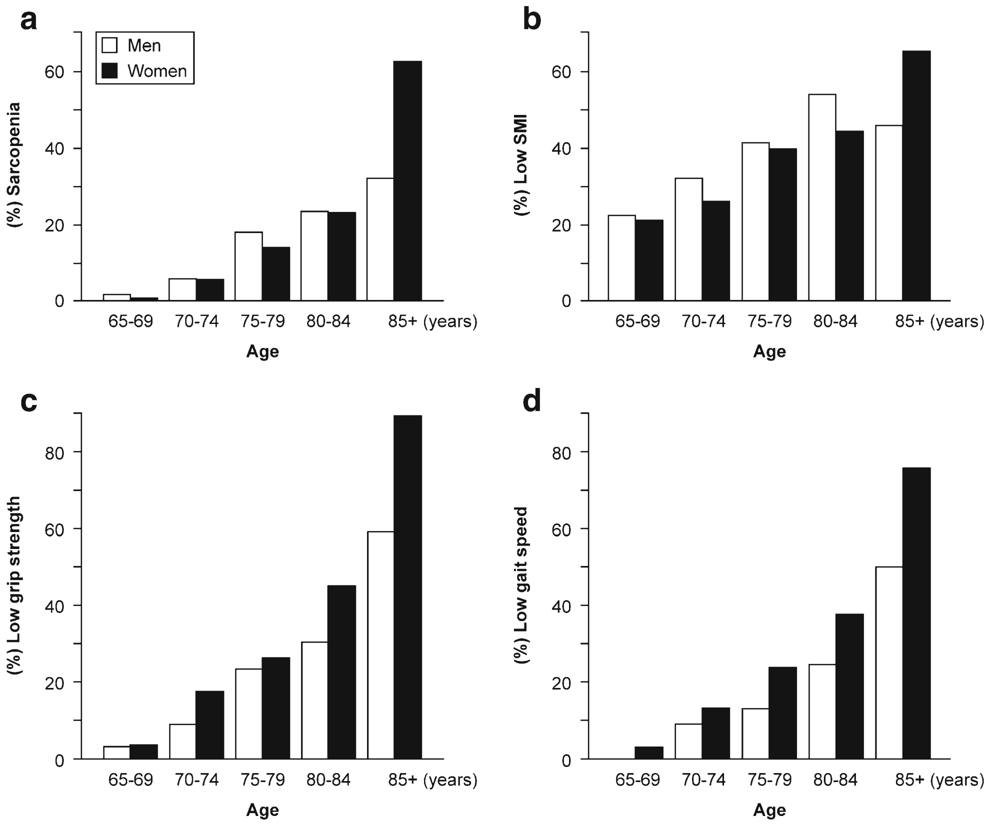

Fig. 1 Percentage of sarcopenia (**a**), low skeletal muscle mass index (*SMI*) (**b**), low grip strength (**c**), and low gait speed (**d**) in men and women in each age stratum (65–69, 70–74, 75–79, 80–85, and ≥85 years). Low SMI was defined as a value of <7.0 kg/m^2 in men and <5.8 kg/m^2 in women. Low grip strength was defined as a value of <30 kg in men and <20 kg in women. Low gait speed was defined as a value of ≤0.8 m/s

Discussion

The present study investigated the prevalence of sarcopenia using the EWGSOP definition in the elderly participants of Japanese population-based cohorts. We determined that age was positively associated with sarcopenia and that BMI was inversely associated, but sex was not. Exercise habit in middle age was associated with increased muscle strength and physical performance and low prevalence of sarcopenia in older age. To the best of our knowledge, this is the first study to show the relationship between exercise habits in middle age and sarcopenia in older age in the elderly participants of population-based cohorts.

Previous studies have reported the prevalence of sarcopenia and its associated factors. For example, Tanimoto and colleagues reported the prevalence of sarcopenia in

Table 2 Factors associated with sarcopenia and exercise habits in middle age in the overall population

Factors associated with sarcopenia	Odds ratio	95 % CI	*P* value
Age (+1 year)	1.20	1.15–1.24	<.001
Sex (women vs. men)	0.98	0.63–1.53	.9
BMI (+1 kg/m^2)	0.68	0.63–0.75	<.001
Chair stand time (+1 s)	1.09[a]	1.04–1.14	.001
One-leg standing time (+1 s)	0.97[a]	0.96–0.99	<.001
Smoking (yes vs. no)	1.86[a]	0.86–4.02	.1
Alcohol consumption (yes vs. no)	1.00[a]	0.60–1.67	.9
Current walking habits (yes vs. no)	0.69[a]	0.42–1.12	.1
Exercise habits in middle age (yes vs. no)	0.53[a]	0.31–0.90	.01
Factors associated with exercise habits in middle age	Regression coefficient	95 % CI	*P* value
SMI	0.09[b]	−0.02–0.19	.1
Grip strength	1.73[c]	1.02–2.44	<.001
Gait speed	0.07[c]	0.04–0.10	<.001
Chair stand time	−0.47[c]	−1.02–0.09	.09
One-leg standing time	4.14[c]	1.26–7.02	.005

BMI body mass index, *CI* confidence interval, *SMI* skeletal muscle mass index

[a] Odds ratio and 95 % CI were calculated by logistic regression analysis after adjusting for age, sex, and BMI

[b] Regression coefficient and 95 % CI were calculated by linear regression analysis after adjusting for age and sex

[c] Regression coefficient and 95 % CI were calculated by linear regression analysis after adjusting for age, sex, and BMI

Table 3 Factors associated with sarcopenia and exercise habits in middle age in men

Factors associated with sarcopenia	Odds ratio	95 % CI	*P* value
Chair stand time (+1 s)	1.09[a]	1.01–1.18	.03
One-leg standing time (+1 s)	0.97[a]	0.95–0.99	.001
Smoking (yes vs. no)	1.49[a]	0.59–3.75	.4
Alcohol consumption (yes vs. no)	0.78[a]	0.40–1.53	.4
Current walking habits (yes vs. no)	0.60[a]	0.28–1.27	.1
Exercise habits in middle age (yes vs. no)	0.48[a]	0.22–1.03	.06
Factors associated with exercise habits in middle age	Regression coefficient	95 % CI	*P* value
SMI	0.16[b]	−0.06 to 0.38	.1
Grip strength	3.17[c]	1.70 to 4.65	<.001
Gait speed	0.10[c]	0.04 to 0.15	.001
Chair stand time	−1.12[c]	−1.95 to −0.28	.009
One-leg standing time	7.81[c]	2.57 to 13.05	.004

CI confidence interval, *SMI* skeletal muscle mass index

[a] Odds ratio and 95 % CI were calculated by logistic regression analysis after adjusting for age and BMI

[b] Regression coefficient and 95 % CI were calculated by linear regression analysis after adjusting for age

[c] Regression coefficient and 95 % CI were calculated by linear regression analysis after adjusting for age and BMI

Japanese community-dwelling elderly individuals based on the EWGSOP definition using bioimpedance analysis (MC-190) [12]. They reported a prevalence of 11.3 % in men and 10.7 % in women [12], which is similar to our results. Although the cut-off value for low SMI was the same in these two studies, the cut-off value used for handgrip strength was different; we used cutoff values of <30 kg in men and <20 kg in women, in accordance with Lauretani and colleagues [20], while they used values of <30.3 kg in men and <19.3 kg in women, based on the lowest quartile of handgrip strength in their study population [12]. In the population of the present study, the lowest quartile of grip strength was 30.5 kg in men and 20.0 kg in women. Considering that these two studies showed similar results, cut-off values of 30 kg in men and 20 kg in women for handgrip strength [20] also may be appropriate for the practical case definition of the EWGSOP algorithm in the Japanese population.

Patel and colleagues reported the prevalence of sarcopenia in Caucasians using the EWGSOP definition, in which low muscle mass is defined as the lowest tertile of lean or fat-free

Table 4 Factors associated with sarcopenia and exercise habits in middle age in women

Factors associated with sarcopenia	Odds ratio	95 % CI	*P* value
Chair stand time (+1 s)	1.08[a]	1.02–1.15	.01
One-leg standing time (+1 s)	0.98[a]	0.96–1.00	.01
Smoking (yes vs. no)	2.44[a]	0.61–9.72	.2
Alcohol consumption (yes vs. no)	1.26[a]	0.58–2.71	.5
Current walking habits (yes vs. no)	0.75[a]	0.39–1.44	.3
Exercise habits in middle age (yes vs. no)	0.55[a]	0.27–1.13	.1
Factors associated with exercise habits in middle age	Regression coefficient	95 % CI	*P* value
SMI	0.06[b]	−0.05 to 0.17	.2
Grip strength	1.03[c]	0.29 to 1.78	.007
Gait speed	0.06[c]	0.01 to 0.10	.01
Chair stand time	−0.12[c]	−0.83 to 0.60	.7
One-leg standing time	2.19[c]	−1.24 to 5.62	.2

CI confidence interval, *SMI* skeletal muscle mass index

[a] Odds ratio and 95 % CI were calculated by logistic regression analysis after adjusting for age and BMI

[b] Regression coefficient and 95 % CI were calculated by linear regression analysis after adjusting for age

[c] Regression coefficient and 95 % CI were calculated by linear regression analysis after adjusting for age and BMI

mass [11]. They recommended use of the lowest tertile of muscle mass as a cut-off value if the reference value of muscle mass in a young healthy population is unavailable. In the population of the present study, the lowest tertile of SMI was 6.92 kg/m^2 in men and 5.80 kg/m^2 in women, which is similar to the cut-off value of <2 SDs of the young adult mean (7.0 kg/m^2 in men and 5.8 kg/m^2 in women) [10]. For evaluating low muscle mass, use of the lowest tertile may be an appropriate alternative method if the reference value of a young healthy population is unavailable.

The present study showed an association between sarcopenia and physical performance, including chair stand time and one-leg standing time, which is consistent with results of previous reports using the EWGSOP definition [11, 13]. However, these were comparisons between sarcopenia and current status of physical performance or exercise habit. Therefore, causal association was unclear whether sarcopenia was caused by decreased physical performance or activity or whether low physical performance or activity was due to sarcopenia. We also revealed that exercise habit in middle age was associated with increased muscle strength and physical performance and low prevalence of sarcopenia in older age. These results suggest that exercise habit in middle age is a protective factor against sarcopenia in older age and effective in maintaining muscle strength and physical performance in older age.

Some sex differences were observed in the present results. Exercise habit in middle age was significantly associated with grip strength and gait speed in older age in both men and women, whereas it was significantly associated with chair stand time and one-leg standing time only in men; however, the sample size of men was smaller than that of women. In the overall population, exercise habit in middle age was not associated with chair stand time; this finding may have been influenced by the fact that the sample size of women was almost twice that of men. The present results suggest that the impact of exercise habit in middle age on physical ability in older age is greater in men than in women.

Since exercise is a modifiable factor, it is a promising finding that exercise habit may be effective in preventing sarcopenia. In the present study, exercise habit was defined as physical activity in the period when the individual was aged 25–50 years, in which subjects practiced sports or physical exercise sufficient to produce sweating or shortness of breath, occasionally or more frequently. Although exercise habit was associated with low prevalence of sarcopenia at the age of ≥65 years, some details remain unclear, including exercise type, intensity, time, and other factors appropriate for prevention of sarcopenia. In addition to the association of the presence of exercise habit in middle age with sarcopenia, we further investigated the association of each category—occasionally, <2 h per week, and ≥2 h per week—with sarcopenia using "never" as a reference. Among the three categories, the analysis could not determine the best frequency and amount of exercise for protection from sarcopenia. The associated ORs for the three categories were comparable, and no dose–response tendency was seen in the relationship between frequency and amount of exercise and prevalence of sarcopenia; the associations also did not reach significance level. The present results suggest that abstaining from exercise during middle age is a risk factor for sarcopenia in older age. Furthermore, the presence of exercise habit in middle age might be much more important than the frequency and amount of exercise. Further studies are necessary to develop intervention programs and to test their effectiveness, along with accumulation of epidemiologic evidence including longitudinal studies.

The present study has several limitations. First, since this was a cross-sectional design, a causal relationship could not be determined. Second, information regarding exercise habits in middle age was obtained by self-report, and there is a possibility of recall bias. Third, the present study included participants who could walk to the survey site and could understand and sign an informed consent form. Since those who did not meet these inclusion criteria were not included in the analyses, the study participants do not truly represent the general population because of health bias. This should be considered when generalizing the results of the present study. Fourth, the results may have been affected by the characteristics of the population, including age and BMI. In the present study, age was positively associated with sarcopenia, whereas BMI was inversely associated with sarcopenia. Therefore, care should be taken when extrapolating the data to other populations with different characteristics, including age and BMI, which may confound the results.

In conclusion, the present study revealed prevalence of sarcopenia in the elderly participants of Japanese population-based cohorts. Exercise habit in middle age was associated with increased muscle strength and physical performance and low prevalence of sarcopenia in older age. These results suggest that exercise habit in middle age is a protective factor against sarcopenia in older age and is effective in maintaining muscle strength and physical performance in older age. Further long-term longitudinal epidemiological studies are necessary to develop effective intervention programs for the prevention and treatment of sarcopenia.

Acknowledgments This study was supported by Grants-in-Aid for Scientific Research (S19109007, B20390182, B23390172, B23390356, and B23390357) from the Japanese Ministry of Education, Culture, Sports, Science and Technology; H17-Men-eki-009, H18-Choujyu-037, H20-Choujyu-009, H21-Chouju-Wakate-011, H22-Chouju-Wakate-007, and H23-Chouju-002 from the Ministry of Health, Labour and Welfare; and Research Aid from the Japanese Orthopaedic Association (JOA-Subsidized Science Project Research 2006–1 and 2010–2).

Conflicts of interest None.

References

1. Rosenberg I (1989) Summary comments: epidemiological and methodological problems in determining nutritional status of older persons. Am J Clin Nutr 50:1231–1233
2. Rosenberg IH (1997) Sarcopenia: origins and clinical relevance. J Nutr 127(5 Suppl):990S–991S
3. Morley JE, Baumgartner RN, Roubenoff R, Mayer J, Nair KS (2001) Sarcopenia. J Lab Clin Med 137(4):231–243
4. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, Martin FC, Michel JP, Rolland Y, Schneider SM, Topinkova E, Vandewoude M, Zamboni M (2010) European Working Group on Sarcopenia in Older People. Sarcopenia: European consensus on definition and diagnosis: report of the European Working Group on Sarcopenia in Older People. Age Ageing 39(4):412–423
5. Delmonico MJ, Harris TB, Lee JS, Visser M, Nevitt M, Kritchevsky SB, Tylavsky FA, Newman AB, Health, Aging and Body Composition Study (2007) Health, Aging and Body Composition Study. Alternative definitions of sarcopenia, lower extremity performance, and functional impairment with aging in older men and women. J Am Geriatr Soc 55(5):769–774
6. Goodpaster BH, Park SW, Harris TB, Kritchevsky SB, Nevitt M, Schwartz AV, Simonsick EM, Tylavsky FA, Visser M, Newman AB (2006) The loss of skeletal muscle strength, mass, and quality in older adults: the health, aging and body composition study. J Gerontol A Biol Sci Med Sci 61(10):1059–1064
7. Baumgartner RN, Koehler KM, Gallagher D, Romero L, Heymsfield SB, Ross RR, Garry PJ, Lindeman RD (1998) Epidemiology of sarcopenia among the elderly in New Mexico. Am J Epidemiol 147(8):755–763
8. Melton LJ 3rd, Khosla S, Crowson CS, O'Connor MK, O'Fallon WM, Riggs BL (2000) Epidemiology of sarcopenia. J Am Geriatr Soc 48(6):625–630
9. Iannuzzi-Sucich M, Prestwood KM, Kenny AM (2002) Prevalence of sarcopenia and predictors of skeletal muscle mass in healthy, older men and women. J Gerontol A Biol Sci Med Sci 57(12):M772–M777
10. Tanimoto Y, Watanabe M, Sun W, Sugiura Y, Tsuda Y, Kimura M, Hayashida I, Kusabiraki T, Kono K (2012) Association between sarcopenia and higher-level functional capacity in daily living in community-dwelling elderly subjects in Japan. Arch Gerontol Geriatr 55(2):e9–e13
11. Patel HP, Syddall HE, Jameson K, Robinson S, Denison H, Roberts HC, Edwards M, Dennison E, Cooper C, Aihie Sayer A (2013) Prevalence of sarcopenia in community-dwelling older people in the UK using the European Working Group on Sarcopenia in Older People (EWGSOP) definition: findings from the Hertfordshire Cohort Study (HCS). Age Ageing 42(3):378–384
12. Tanimoto Y, Watanabe M, Sun W, Tanimoto K, Shishikura K, Sugiura Y, Kusabiraki T, Kono K (2013) Association of sarcopenia with functional decline in community-dwelling elderly subjects in Japan. Geriatr Gerontol Int. doi:10.1111/ggi.12037
13. Lin CC, Lin WY, Meng NH, Li CI, Liu CS, Lin CH, Chang CK, Lee YD, Lee CC, Li TC (2013) Sarcopenia prevalence and associated factors in an elderly Taiwanese metropolitan population. J Am Geriatr Soc 61(3):459–462
14. National Institute of Population and Society Research. Population projections for Japan (January 2012): 2011 to 2060. http://www.ipss.go.jp/site-ad/index_english/esuikei/gh2401e.asp. Accessed 30 May 2013
15. Ministry of Health, Labour and Welfare. The outline of the results of National Livelihood Survey 2010. http://www.mhlw.go.jp/toukei/saikin/hw/k-tyosa/k-tyosa10/4-2.html. Accessed 30 May 2013
16. Yoshimura N, Muraki S, Oka H, Kawaguchi H, Nakamura K, Akune T (2010) Cohort profile: research on Osteoarthritis/Osteoporosis Against Disability study. Int J Epidemiol 39(4):988–995
17. Yoshimura N, Muraki S, Oka H, Mabuchi A, En-Yo Y, Yoshida M, Saika A, Yoshida H, Suzuki T, Yamamoto S, Ishibashi H, Kawaguchi H, Nakamura K, Akune T (2009) Prevalence of knee osteoarthritis, lumbar spondylosis, and osteoporosis in Japanese men and women: the research on osteoarthritis/osteoporosis against disability study. J Bone Miner Metab 27(5):620–628
18. Shimada H, Lord SR, Yoshida H, Kim H, Suzuki T (2007) Predictors of cessation of regular leisure-time physical activity in community-dwelling elderly people. Gerontology 53(5):293–297
19. Yoshimura N, Oka H, Muraki S, Akune T, Hirabayashi N, Matsuda S, Nojiri T, Hatanaka K, Ishimoto Y, Nagata K, Yoshida M, Tokimura F, Kawaguchi H, Nakamura K (2011) Reference values for hand grip strength, muscle mass, walking time, and one-leg standing time as indices for locomotive syndrome and associated disability: the second survey of the ROAD study. J Orthop Sci 16(6): 768–777
20. Lauretani F, Russo CR, Bandinelli S, Bartali B, Cavazzini C, Di Iorio A, Corsi AM, Rantanen T, Guralnik JM, Ferrucci L (2003) Age-associated changes in skeletal muscles and their effect on mobility: an operational diagnosis of sarcopenia. J Appl Physiol 95(5):1851–1860
21. No authors listed (1996) Bioelectrical impedance analysis in body composition measurement: National Institutes of Health Technology Assessment Conference Statement. Am J Clin Nutr 64(3 Suppl): 524S-532S
22. Janssen I, Heymsfield SB, Baumgartner RN, Ross R (2000) Estimation of skeletal muscle mass by bioelectrical impedance analysis. J Appl Physiol 89(2):465–471
23. Kyle UG, Genton L, Slosman DO, Pichard C (2001) Fat-free and fat mass percentiles in 5225 healthy subjects aged 15 to 98 years. Nutrition 17(7–8):534–541
24. Kyle UG, Genton L, Karsegard L, Slosman DO, Pichard C (2001) Single prediction equation for bioelectrical impedance analysis in adults aged 20–94 years. Nutrition 17(3):248–253
25. Roubenoff R, Baumgartner RN, Harris TB, Dallal GE, Hannan MT, Economos CD, Stauber PM, Wilson PW, Kiel DP (1997) Application of bioelectrical impedance analysis to elderly populations. J Gerontol A Biol Sci Med Sci 52(3):M129–M136
26. Nemoto M, Yasbushita N, Kim M, Tomoaki M, Satoshi S, Jung S, Hiroyuki S, Kiyoji T (2012) Validity of the bioelectrical impedance method for assessing body composition in non-frail and pre-frail older adults. Int J Body Comps Res 10:225–262

Osteoarthritis and Cartilage 22 (2014) 104–110

Osteoarthritis and Cartilage

Prevalence and distribution of intervertebral disc degeneration over the entire spine in a population-based cohort: the Wakayama Spine Study

M. Teraguchi †, N. Yoshimura ‡, H. Hashizume † *, S. Muraki §, H. Yamada †, A. Minamide †, H. Oka ‡, Y. Ishimoto †, K. Nagata †, R. Kagotani †, N. Takiguchi †, T. Akune §, H. Kawaguchi ||, K. Nakamura ¶, M. Yoshida †

† *Department of Orthopaedic Surgery, Wakayama Medical University, Wakayama, Japan*
‡ *Department of Joint Disease Research, 22nd Century Medical & Research Center, Faculty of Medicine, The University of Tokyo, Tokyo, Japan*
§ *Department of Clinical Motor System Medicine, 22nd Century Medical & Research Center, Faculty of Medicine, The University of Tokyo, Tokyo, Japan*
|| *Department of Sensory & Motor System Medicine, Faculty of Medicine, The University of Tokyo, Tokyo, Japan*
¶ *Rehabilitation Services Bureau, National Rehabilitation Center for Persons with Disabilities, Saitama, Japan*

ARTICLE INFO

Article history:
Received 23 May 2013
Accepted 29 October 2013

Keywords:
Magnetic resonance imaging
Population-based cohort
Intervertebral disc degeneration
Entire spine
Prevalence
Distribution

SUMMARY

Objectives: The purposes of this study were to investigate the prevalence and distribution of intervertebral disc degeneration (DD) over the entire spine using magnetic resonance imaging (MRI), and to examine the factors and symptoms potentially associated with DD.

Design: This study included 975 participants (324 men, mean age of 67.2 years; 651 women, mean age of 66.0 years) with an age range of 21–97 years in the Wakayama Spine Study. DD on MRI was classified into Pfirrmann's system (grades 4 and 5 indicating DD). We assessed the prevalence of DD at each level in the cervical, thoracic, and lumbar regions and the entire spine, and examined DD-associated factors and symptoms.

Results: The prevalence of DD over the entire spine was 71% in men and 77% in women aged <50 years, and >90% in both men and women aged >50 years. The prevalence of an intervertebral space with DD was highest at C5/6 (men: 51.5%, women: 46%), T6/7 (men: 32.4%, women: 37.7%), and L4/5 (men: 69.1%, women: 75.8%). Age and obesity were associated with the presence of DD in all regions. Low back pain was associated with the presence of DD in the lumbar region.

Conclusion: The current study established the baseline data of DD over the entire spine in a large population of elderly individuals. These data provide the foundation for elucidating the causes and mechanisms of DD.

Introduction

Intervertebral disc degeneration (DD) is thought to be the first step in degenerative spinal changes[1], and is typically followed by the gradual formation of osteophytes, disc narrowing, and spinal stenosis[2,3]. Furthermore, DD is considered to be one of the causes of several symptoms (neck pain or low back pain)[4–7]. Therefore, in terms of developing preventive strategies for spinal disorders, it will be important to obtain fundamental data on DD (prevalence, distribution, associated factors, etc.) in a population-based cohort.

We believe that the analysis of DD over the entire spine would provide more useful data than that of DD in the cervical, thoracic, or lumbar regions, separately. In particular, investigations on the extent of DD in these three regions using whole spine magnetic resonance imaging (MRI) could provide useful data concerning intra-individual factors in the development of DD. Several studies have examined degenerative changes in only cervical and lumbar discs because of the high susceptibility to DD in these regions[8–12]. As well, several previous studies have investigated the aging process of the intervertebral discs in the cervical and lumbar regions using MRI in population-based cohorts[13,14]. However, degenerative changes in the thoracic region and correspondingly over the entire spine are poorly understood, because DD in the thoracic region is considered to be an uncommon problem[15,16]. In particular, the stabilization of the thoracic region by the thoracic cage, which

* Address correspondence and reprint requests to: H. Hashizume, Wakayama Medical University, 811-1 Kimiidera, Wakayama City, Wakayama 641-8510, Japan. Tel: 81-73-447-2300; Fax: 81-73-448-3008.
E-mail address: hashizum@wakayama-med.ac.jp (H. Hashizume).

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http://dx.doi.org/10.1016/j.joca.2013.10.019

reduces the mechanical stress imposed on the intervertebral discs, is believed to reduce the incidence of degenerative diseases in this region[17].

Consistent with the above-mentioned previous studies, a population-based cohort analysis of DD in the different spinal regions using MRI could be used to examine the distribution of DD over the entire spine. However, to our knowledge, no previous studies have performed this type of investigation with a population-based cohort.

From the perspective of discogenic pain, the association between DD and symptoms remains controversial, although several reports have found that DD was a source of low back pain[4,5]. Moreover, reports on the association between the presence of DD in the cervical and thoracic regions and neck pain are rare[6,7]. Further, these studies were not performed with population-based cohorts and did not use whole spine MRI. Thus, no study has assessed neck pain and low back pain within individuals using whole spine MRI. To clarify the points described above, we established a population-based cohort study in which participants underwent whole spine MRI and were examined for symptoms associated with spinal disorders. This is our first report of DD over the entire spine based on a cross-sectional examination of a baseline population.

The aims of this study were to examine (1) the prevalence and distribution of DD over the entire spine using MRI in a population-based cohort, (2) the factors associated with DD (age, gender, and body mass index [BMI]) in the cervical, thoracic, and lumbar regions, and (3) the association between DD and symptoms (neck pain and low back pain).

Methods

Participants

The present study, entitled the Wakayama Spine Study, was performed with a sub-cohort of the second visit of the ROAD (Research on Osteoarthritis/osteoporosis Against Disability) study, which was initiated as a nationwide, prospective study of bone and joint diseases in population-based cohorts; the cohorts were established in three communities with different characteristics (i.e., urban, mountainous, and coastal regions) in Japan. A detailed profile of the ROAD study has already been described elsewhere[18,19]. Here, we briefly summarize the profile of the present study. The second visit of the ROAD study began in 2008 and was completed in 2010. All the participants in the baseline study were invited to participate in the second visit. In addition to the former participants, inhabitants aged 60 years and older in the urban area and those aged 40 years and younger in the mountainous and coastal areas who were willing to participate in the ROAD survey were also included in the second visit (both the mountainous and coastal areas were in Wakayama prefecture). Finally, 2674 individuals (900 men, 1774 women) participated in the second visit of the ROAD study, and comprised 1067 individuals (353 men, 714 women) in the urban area, 742 individuals (265 men, 477 women) in the mountainous area, and 865 individuals (282 men, 583 women) in the coastal area. Among these three communities in the ROAD study, the mountainous and coastal areas from which we invited all 1607 participants (547 men, 1060 women) to the Wakayama Spine Study are located in Wakayama prefecture. Of the 1607 participants, a total of 1011 individuals provided written informed consent and attended the Wakayama Spine Study with MRI examinations[20,21]. Among the 1011 participants, those who had MRI-sensitive implanted devices (e.g., pacemakers) and other disqualifiers were excluded. Consequently, 980 individuals underwent MRI of the whole spine. Furthermore, one participant who had undergone a previous cervical operation and four participants who had undergone a previous posterior lumbar fusion were excluded from the analysis. Finally, whole spine MRI results were available for 975 participants (324 men, 651 women) with an age range of 21–97 years (mean, 67.2 years for men and 66.0 years for women). Table I shows the demographic and baseline characteristics of the 975 participants in the present study.

For the purpose of analysis, the participants were divided into five age groups: (1) under 50 years, (2) 50–59 years, (3) 60–69 years, (4) 70–79 years, and (5) 80 years and over. The anthropometric measurements included height, weight, and BMI (weight [kg]/height^2 [m^2]). BMI was categorized according to the guidelines for Asians proposed by the World Health Organization and was thus defined as follows: underweight, less than 18.5; normal, 18.5–23; overweight, 23–27.5; and obesity, greater than 27.5[22]. Experienced orthopedists also asked all participants the following question regarding neck pain and low back pain: “Have you experienced neck pain on most days during the past month, in addition to now?” and “Have you experienced low back pain on most days during the past month, in addition to now?” Those who answered “yes” were defined as having neck pain or low back pain based on previous studies[23–26].

MRI

A mobile MRI unit (Excelart 1.5 T, Toshiba, Tokyo, Japan) was used in the present study, and whole spine MRI was performed for all participants on the same day as the examination. The participants were supine during the MRI, and those with rounded backs used triangular pillows under their head and knees. The imaging protocol included sagittal T2-weighted fast spin echo (FSE) (repetition time [TR]: 4000 ms/echo, echo time [TE]: 120 ms, field of view [FOV]: 300 × 320 mm), and axial T2-weighted FSE (TR: 4000 ms/echo, TE: 120 ms, FOV: 180 × 180 mm).

Sagittal T2-weighted images were used to assess the intervertebral space from C2/3 to L5/S1. C2/3 to C7/T1, T1/2 to T12/L1, and L1/2 to L5/S1 were defined as the cervical region, thoracic region, and lumbar region, respectively. DD grading was performed by an

Table I
Characteristics of participants

	Overall	Men	Women
No. of participants	**975**	**324**	**651**
Age strata (years)			
<50	125	38	87
50–59	175	59	116
60–69	223	65	158
70–79	261	89	172
≧80	191	73	118
Demographic characteristics			
Age, years	66.4 ± 13.5	67.2 ± 13.9	66.0 ± 13.4
Height, cm	156.4 ± 9.4	164.6 ± 7.2	151.5 ± 7.2
Weight, kg	56.8 ± 11.5	64.5 ± 11.6	53.0 ± 9.4
BMI (kg/m^2)	23.3 ± 3.6	23.6 ± 3.4	23.1 ± 3.7
BMI (WHO-Asian category) (*N*)			
Underweight	61	16	45
Normal	425	124	300
Overweight	361	139	221
Obesity	128	44	84
Baseline characteristics			
Symptoms (%)			
Neck pain	24.9	19.4	27.7
Low back pain	43	36.7	42.1
Life style (%)			
Smoking	10.7	25.2	4.1
Alcohol consumption	31.4	56.8	18.8

BMI category for Asian was based on World Health Organization (WHO) guidelines defining underweight (<18.5), normal (18.5–23), overweight (23–27.5), and obese (>27.5). Values are the means ± standard deviation.

orthopedist (MT) who was blind to the background of the subjects. The degree of DD on MRI was classified into five grades based on Pfirrmann's classification system[27], with grades 4 and 5 indicating DD. As shown in Fig. 1, the signal intensity for grade 4 was intermediate to hypointense to the cerebrospinal fluid (dark gray), while the structure is inhomogeneous. Meanwhile, for grade 5, the signal intensity is hypointense to the cerebrospinal fluid (black), and the structure is likewise inhomogeneous. In addition, the disc space is collapsed. It has been reported that loss of signal intensity is significantly associated with the morphological level of the DD and is also associated with both the water and proteoglycan content in a disc[28]. Therefore, we used a grading based on signal intensity and disc height. For evaluating intraobserver variability, 100 randomly selected magnetic resonance images of the entire spine were rescored by the same observer (MT) more than 1 month after the first reading. Furthermore, to evaluate interobserver variability, 100 other magnetic resonance images were scored by two orthopedists (MT and RK) using the same classification. The intraobserver and interobserver variability for DD, as evaluated by kappa analysis, was 0.94 and 0.94, respectively.

"Prevalence of DD", which was defined as "the proportion of the number of participants who had DD at each intervertebral space or region or over the entire spine divided by the total number of participants", was used to describe the frequency of the presence of DD. In the analysis, to clarify the associated factors using multiple logistic regression analysis, we entered a variable of prevalence state (1, presence; 0, absence) of DD as a dependent variable.

Statistical analysis

Multiple logistic regression analysis was used to estimate the association between the presence of DD in each region (cervical, thoracic, and lumbar) as dependent variables and the age group, gender, and BMI category as nominal independent variables after adjustment for the age group, gender and BMI category, mutually.

Additionally, multiple logistic regression analysis was used to estimate the association between the presence of neck pain or low back pain and the presence of DD in each region after adjustment for age, gender, and BMI. Furthermore, in cases in which the presence of DD was significantly associated with a symptom, we examined as a sub-analysis the association between the presence of neck pain or low back pain and the number of DD (categorized into "0", "1 or 2", "3 or more" for ready assessment) in each region using multiple logistic regression analysis after adjustment for age, gender, and BMI. All statistical analyses were performed using JMP version 8 (SAS Institute Japan, Tokyo, Japan).

Results

As shown in Table II, the prevalence of DD in the cervical and thoracic regions and over the entire spine increased with the elevation of the age strata in both men and women. For both genders, the prevalence of DD in the lumbar region was also increased with the elevation of the age strata up to the 70-year-old age group but decreased in the 80-year-old age group. Table III

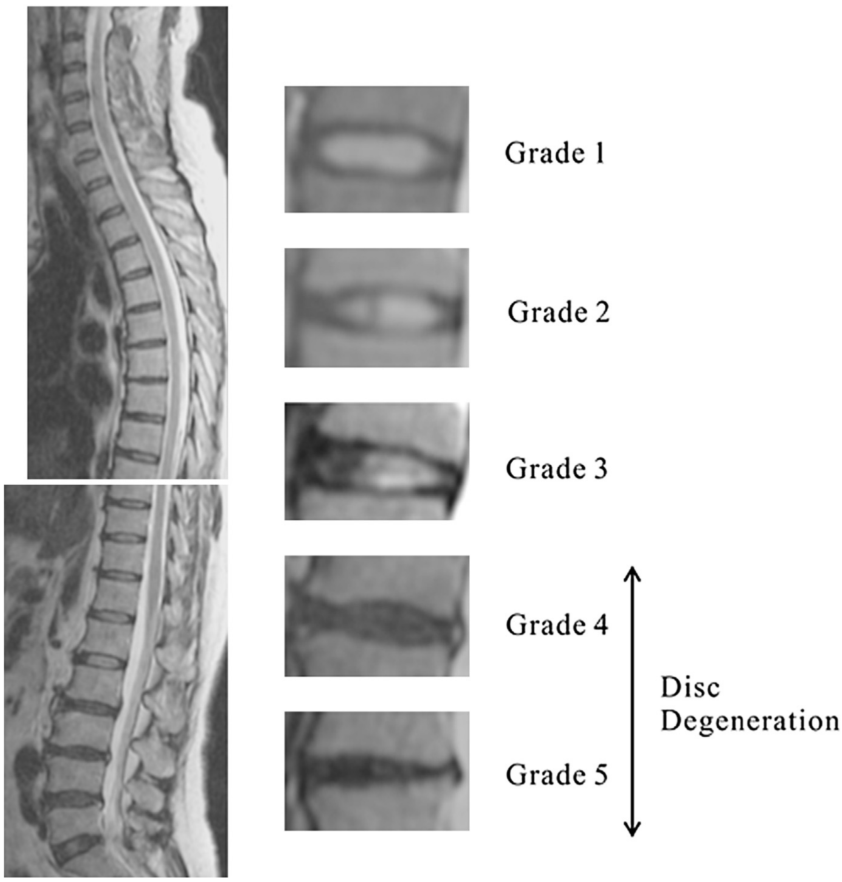

Fig. 1. Mid-sagittal view on T2-weighted images of the whole spine MRI with Pfirrmann classification. The grade is described according to Pfirrmann classification. Grades 4 and 5 were considered degenerated. The signal intensity for grade 4 was intermediate to hypointense to the cerebrospinal fluid (dark gray), while the structure is inhomogeneous. Meanwhile, for grade 5, the signal intensity is hypointense to the cerebrospinal fluid (black), and the structure is also inhomogeneous. Additionally, the disc space is collapsed.

shows the prevalence of intervertebral spaces with DD over the entire spine for the participants in this study. The three highest prevalence levels of DD in the intervertebral spaces in the cervical, thoracic, and lumbar regions were as follows. The prevalence at C5/6 was 51.5% (95% CI: 46.1–56.3) in men and 46% (95% CI: 42.2–49.9) in women, followed by the prevalence at C6/7 of 43.5% in men and 33.3% in women, and at C4/5 of 38.6% in men and 35.8% in women. The prevalence at T6/7 was 32.4% (95% CI: 27.5–37.6) in men and 37.7% (95% CI: 34.1–41.5) in women, followed by the prevalence at T7/8 of 31.8% in men and 36.2% in women, and at T5/6 of 28.4% in men and 35.9% in women. The prevalence at L4/5 was 69.1% (95% CI: 63.9–73.9) in men and 75.8% (95% CI: 72.3–78.9) in women, followed by that at L5/S1 of 66.7% in men and 70.9% in women, and at L3/4 of 59.3% in men and 61.9% in women.

An older age was significantly associated with the presence of DD in each region. Gender was not significantly associated with the presence of DD in each region, although men demonstrated a tendency for a greater number of DD than women in the cervical region. In addition, overweight status (BMI: 23–27.5) was a significantly associated factor in the cervical and thoracic regions, and obesity (BMI: >27.5) was a significantly associated factor in all regions compared with participants of a normal weight (BMI: 18.5–23) (Table IV).

The participants with DD in the cervical region did not significantly differ in terms of the presence of neck pain (OR 0.88, 95% CI: 0.63–1.22, $P = 0.53$). The presence of DD in the thoracic region was not significantly associated with neck pain (OR 0.84, 95% CI: 0.60–1.19, $P = 0.33$) and low back pain (OR 1.08, 95% CI: 0.80–1.47, $P = 0.60$). However, the presence of DD in the lumbar region was significantly associated with low back pain (OR 1.57, 95% CI: 1.02–2.49, $P < 0.05$). Moreover, in a sub-analysis, we investigated the association between low back pain and the number of DD in the lumbar region ("0", "1 or 2", "3 or more"). The presence of low back pain was significantly higher in participants with three or more DD (OR 1.75, 95% CI: 1.11–2.81, $P < 0.05$), but not in those with one or two DD (OR 1.34, 95% CI: 0.84–2.20, $P = 0.22$), as compared with participants without DD.

Discussion

This study is the first to report the prevalence and distribution of DD over the entire spine using whole spine MRI in a population-based cohort. The prevalence of DD over the entire spine and in each of the three spinal regions was higher in older participants. In addition, we noted that the presence of DD was significantly associated with low back pain in the lumbar region but not with neck pain in the cervical region.

Battié *et al.* reviewed the prevalence of DD in the lumbar region and noted that it ranged from 20% to 83%[29]. Consistent with the observations of this review, other reported prevalence levels of DD in the lumbar region have shown wide variation between samples and have often been quite high because the studies had certain drawbacks, including relatively small sample sizes[1,30], narrow age ranges[5,31], and asymptomatic subjects[32]. However, no previous study has assessed the prevalence of DD over the entire spine using whole spine MRI. We noted that the prevalence of DD over the entire spine exceeded 70% in participants less than 50 years of age and was greater than 90% in participants older than 50 years of age.

Table II
Prevalence of DD by age strata in men and women

	Entire spine		Cervical		Thoracic		Lumbar	
	Men	Women	Men	Women	Men	Women	Men	Women
Age strata (years)								
<50	71.0	77.0	26.3	27.9	15.7	11.4	55.2	71.2
50–59	91.5	93.1	47.4	49.1	49.1	35.3	86.4	91.3
60–69	98.4	95.5	66.1	54.4	61.5	63.2	96.9	94.3
70–79	95.8	99.4	80.9	72.0	73.0	79.6	96.6	96.5
≧80	93.2	97.4	86.3	85.5	79.4	88.9	82.1	84.5

Values are percentage.

Little epidemiological data are available concerning DD in the intervertebral space using MRI assessments in a population-based cohort. Matsumoto *et al.*[4] reported that the prevalence of DD in the cervical region was the highest at C5/6 (86% in men and 89% in women over the age of 60 years). In addition, Hanagai *et al.*[33] and Kanayama *et al.*[34] reported that the prevalence of DD in the lumbar region was the highest at L4/5 (67%; mean age 68.4 years) and L5/S1 (49.5%; mean age 39.7 years), respectively. In the present study, the prevalence of DD was the highest at C5/6 (51.5% in men and 46.0% in women) and L4/5 (69.1% in men and 75.8% in women). The prevalence of cervical DD in the previous study by Matsumoto *et al.*[4] was higher than that in the present study. However, the subjects were recruited from volunteers in the hospital rather than a population; thus, the capacity for strict comparisons are limited. Furthermore, few studies have reported age-related DD in the thoracic region. Matsumoto *et al.* reported that the highest prevalence of DD occurred at T7/8 (30.9%; mean age 48.0 y) followed by T6/7 in the thoracic region; however, all 94 participants in this report were asymptomatic[35]. In the present study, we confirmed a high prevalence of DD at T6/7 in the thoracic region. This finding is supported by results from thoracic MRI investigations demonstrating a high prevalence of DD in asymptomatic individuals.

The distribution of prevalence of DD was similar to the alignment of the spine in the sagittal plane, such as cervical lordosis (C3–C7), thoracic kyphosis (T1–T12), and lumbar lordosis (L1–L5)[36]. The high prevalence of DD in the lumbar region can potentially be explained by mechanical stress. Our results support the hypothesis that compressive stress affected DD, since compressive stresses are the highest in the mid-thoracic region of the entire spine[37]. Mechanical stress on the thoracic intervertebral disc is reduced due to stabilization by the thoracic cage, and therefore, the thoracic intervertebral disc may be affected by the detrimental effect of compressive stress caused by posture on the sagittal balance of the spine[38]. This study also provides the first mapping of intervertebral spaces with DD over the entire spine by MRI analysis, which adds to our knowledge of the distribution of prevalence of DD in the cervical, thoracic, and lumbar regions, which has been reported only fragmentarily in previous reports.

Our current results confirmed that age was a significant factor associated with the presence of DD in all three regions. Previous studies reported that the association of DD to factors such as height, weight, and gender was uncertain; however, age, obesity, smoking, and occupation have been suggested to be DD-associated factors[39–42]. The previous studies focused almost entirely on the lumbar region, and the identification of associated factors may be challenging for this region because it is affected to a greater extent by various factors, including mechanical stress. Moreover, it remains unknown what other factors (beyond age) are associated with DD in the cervical and thoracic regions[6,13]. In the present study, overweight and obesity significantly influenced DD in the cervical and thoracic regions (cervical; OR: overweight 1.38 [95% CI 1.00–1.90], obesity 1.60 [95% CI 1.04–2.51], thoracic; OR: overweight 1.64 [95% CI 1.17–2.29], obesity 3.12 [95% CI 1.91–5.19]), and obesity also significantly influenced DD in the lumbar region (OR: 2.56 [95% CI 1.20–6.14]). In a previous study, Samartzis *et al.* reported that DD in the lumbar region was significantly associated with overweight and obesity[39]. However, DD in the cervical and thoracic region did not demonstrate a significant association with BMI, as reported by Okada *et al.*[6] and Matsumoto *et al.*[35]. Of note, the previous studies were

Table III
Prevalence of intervertebral spaces with DD over the entire spine by age strata in men and women

Age strata (years)	C2/3	C3/4	C4/5	C5/6	C6/7	C7/T1	T1/2	T2/3	T3/4	T4/5	T5/6	T6/7	T7/8	T8/9	T9/10	T10/11	T11/12	T12/L1	L1/2	L2/3	L3/4	L4/5	L5/S1
Men																							
Total	28.3	30.2	38.6	51.5	43.5	26.8	20.3	23.4	22.2	24.0	28.4	32.4	31.8	28.7	31.4	25.0	24.0	17.5	30.0	51.5	59.3	69.1	66.7
<50	10.5	10.5	13.1	15.7	13.1	5.2	5.2	7.8	7.8	5.2	10.5	7.8	5.2	2.6	2.6	2.6	0.0	0.0	2.6	10.5	7.8	34.2	47.3
50–59	6.7	11.8	15.2	37.2	27.1	10.1	8.4	6.7	11.8	11.8	16.9	23.7	27.1	16.9	20.3	16.9	13.5	5.1	15.2	35.5	61.0	74.5	50.8
60–69	35.3	36.9	49.2	50.7	40.0	21.0	20.0	24.6	23.0	27.6	27.6	35.3	32.3	36.9	41.5	23.0	24.6	18.4	40.0	60.0	69.0	76.9	75.3
70–79	35.9	35.9	49.4	64.0	51.6	34.8	24.7	26.9	25.8	30.3	33.7	38.2	41.5	35.9	40.4	37.0	31.4	26.9	39.3	69.6	73.0	79.7	79.7
≧80	39.7	42.4	47.9	67.1	65.7	46.5	32.8	39.7	32.8	32.8	41.0	42.4	36.9	35.6	35.6	30.1	35.6	24.6	39.7	56.1	58.9	63.0	65.7
Women																							
Total	21.9	24.8	35.8	46.0	33.3	13.6	15.2	23.1	29.8	31.7	35.9	37.7	36.2	34.2	32.7	28.7	23.8	20.0	31.7	49.7	61.9	75.8	70.9
<50	2.2	3.4	10.3	20.6	10.3	1.1	0.0	1.1	4.5	0.0	1.1	4.5	3.4	5.7	4.5	4.5	1.1	0.0	4.5	12.6	18.3	49.4	56.3
50–59	11.2	9.4	23.2	36.2	23.2	3.4	6.8	12.0	15.5	15.5	16.3	18.1	19.8	12.9	13.7	10.3	6.9	6.9	15.6	35.6	55.6	73.9	70.4
60–69	13.9	20.8	31.0	43.6	29.1	11.3	13.2	18.3	29.7	32.2	37.9	39.8	31.6	32.2	30.3	19.6	15.8	14.5	25.3	55.0	66.4	85.4	75.9
70–79	33.7	34.8	46.5	53.4	42.4	16.2	22.0	34.3	41.2	44.7	50.0	50.0	47.0	45.9	44.7	42.4	34.3	26.1	44.7	64.5	80.2	86.0	81.9
≧80	40.6	46.6	57.6	66.9	52.5	32.2	27.1	40.6	45.7	51.6	57.6	61.0	66.9	61.8	57.6	56.7	52.9	46.1	57.2	62.3	67.5	69.2	58.9

Values are percentage.

conducted with asymptomatic healthy subjects. Therefore, based on our findings, obesity appears to have some influence on the process of DD over the entire spine.

An association between DD in the lumbar region and low back pain was previously demonstrated in a twin study[43]. Moreover, Okada *et al.*[6] reported an association between neck pain and DD in the cervical region, whereas Arana *et al.*[7] found an association between neck pain and DD in the upper thoracic region. Of interest, no agreement has been reached regarding the most appropriate definition of neck pain and low back pain in population cohorts[7]. Nonetheless, we observed a significant association between the presence of DD in the lumbar region and low back pain.

The present study has several limitations. First, it was a cross-sectional study, and therefore, the transition to DD cannot be clarified. Second, the participants included in the present study may not represent the general population, since they were recruited from only two local areas. To confirm whether the participants of the Wakayama Spine Study are representative of the Japanese population, we compared the anthropometric measurements and frequencies of smoking and alcohol consumption between the general Japanese population and the study participants. No significant differences in BMI were observed (men: 24.0 and 23.7, $P = 0.33$; women: 23.5 and 23.1, $P = 0.07$). Further, the proportion of current smokers and those who consumed alcohol (those who regularly smoked or consumed alcohol more than once per month) in men and the proportion of those who consumed alcohol in women were significantly higher in the general Japanese population than in the study population, whereas there was no significant difference in the proportion of current smokers in women (male smokers, 32.6% and 25.2%, $P = 0.015$; female smokers, 4.9% and 4.1%, $P = 0.50$; men who consumed alcohol, 73.9% and 56.8%, $P < 0.0001$; women who consumed alcohol, 28.1% and 18.8%, $P < 0.0001$). These results suggest the likelihood that in this study, participants had healthier lifestyles than those of the general Japanese population[44]. This "healthy" selection bias should be taken into consideration when generalizing the results obtained from the Wakayama Spine Study. Third, the Pfirrmann classification introduced a comprehensive MRI grading system based on the assessment of structure, the distinction of the nucleus and annulus fibrosis, the signal intensity[28], and the height of the intervertebral discs[27]. However, bony endplate alterations, osteophyte changes, spinal stenosis, and disc protrusion are not covered by the Pfirrmann classification. Therefore, it is necessary to perform investigations that include these morphological changes. Finally, the accurate measurement of obesity, such as abdominal obesity and/or body composition, might reveal that obesity has a stronger association with DD; however, the present study examined only BMI as a measurement of obesity. Thus, we plan to examine the girth of the abdomen and body composition using electrical impedance in the assessment of human body composition (the BIA method) in a future study.

In conclusion, this study is the first one to investigate the prevalence of DD over the entire spine in a large population of individuals to establish baseline data for a prospective longitudinal

Table IV
Multiple logistic regression of the association with presence of DD with age, BMI, and gender

	Cervical	Thoracic	Lumbar
	OR (95% CI)	OR (95% CI)	OR (95% CI)
Age group (years)			
<50	1	1	1
50–59 (vs <50)	2.45 (1.5–4.06)**	4.60 (2.53–8.76)***	4.47 (2.44–8.48)***
60–69 (vs <50)	3.62 (2.26–5.91)***	12.0 (6.77–22.7)***	9.95 (5.02–21.3)***
70–79 (vs <50)	7.87 (4.86–12.9)***	24.9 (13.8–47.6)***	15.0 (7.26–34.5)***
≧80 (vs <50)	16.9 (9.68–30.5)***	47.0 (24.5–95.6)***	2.94 (1.71–5.13)**
Men (vs women)	1.20 (0.89–1.64)	0.88 (0.64–1.21)	0.70 (0.45–1.09)
BMI (WHO-Asian category)			
Underweight (vs normal)	0.91 (0.49–1.70)	1.36 (0.71–2.67)	0.81 (0.38–1.84)
Normal	1	1	1
Overweight (vs normal)	1.38 (1.00–1.90)*	1.64 (1.17–2.29)*	1.14 (0.71–1.85)
Obesity (vs normal)	1.60 (1.04–2.51)*	3.12 (1.91–5.19)***	2.56 (1.20–6.14)*

BMI category for Asian was based on World Health Organization (WHO) guidelines defining underweight (<18.5), normal (18.5–23), overweight (23–27.5), and obese (>27.5). OR = odds ratio, CI = confidential interval.
*$P < 0.05$, **$P < 0.001$, ***$P < 0.0001$.

study. The prevalence of intervertebral spaces with DD was the highest at C5/6, T6/7, and L4/5 in the cervical, thoracic, and lumbar regions, respectively. DD in the cervical, thoracic, and lumbar regions was significantly associated with age and obesity. A significant positive association was observed between the presence of DD in the lumbar region and low back pain.

Author contributions

All authors worked collectively to develop the protocols and method described in this paper. MT, NY, SM, HO, YI, KN, NT, and TA were principal investigators responsible for the fieldwork in the Wakayama Spine study. MT and SM performed the statistical analysis. All authors contributed to the analysis and interpretation of results. MT wrote the report. All authors read and approved the final manuscript.

Role of the funding source

The sponsors had no role in study design, data collection, data analysis, data interpretation, or in writing of the report.

Conflict of interest

The authors declare no conflicts of interest.

Acknowledgments

This study was supported by a Grant-in-Aid for Scientific Research (B20390182, B23390357, C20591737, C20591774), and for Exploratory Research (19659305) from the Japanese Ministry of Education, Culture, Sports, Science and Technology, H17-Men-eki-009, H18-Choujyu-037, and H20-Choujyu-009 from the Ministry of Health, Labour and Welfare, Research Aid from the Japanese Orthopaedic Association, a Grant from the Japanese Orthopaedics and Traumatology Foundation, Inc. (No. 166), and a Grant-in-Aid for Scientific Research, Scientific Research (C22591639) from the Japanese Society for the Promotion of Science.

The authors wish to thank Mrs Tomoko Takijiri and other members of the Public Office in Hidakagawa Town, and Mrs Tamako Tsutsumi, Mrs Kanami Maeda, and other members of the Public Office in Taiji Town for their assistance in the location and scheduling of participants for examinations.

References

1. Boos N, Weissbach S, Rohrbach H, Weiler C, Spratt KF, Nerlich AG. Classification of age-related changes in lumbar intervertebral discs: 2002 Volvo Award in basic science. Spine 2002;27:2631–44.
2. Kirkaldy-Willis WH, Farfan HF. Instability of the lumbar spine. Clin Orthopedics Relat Res 1982;165:110–23.
3. Ahn TJ, Lee SH, Choi G, Ahn Y, Liu WC, Kim HJ, *et al.* Effect of intervertebral disk degeneration on spinal stenosis during magnetic resonance imaging with axial loading. Neurol Med Chir 2009;49:242–7.
4. Sambrook PN, MacGregor AJ, Spector TD. Genetic influences on cervical and lumbar disc degeneration: a magnetic resonance imaging study in twins. Arthritis Rheum 1999;42:366–72.
5. Kjaer P, Laboeuf-Yde C, Korsholm L, Sorensen JS, Bendix T. Magnetic resonance imaging and low back pain in adults: a diagnostic imaging study of 40-year-old men and women. Spine 2005;30:1173–80.
6. Okada E, Matsumoto M, Ichihara D, Chiba K, Toyama Y, Fujiwara H, *et al.* Aging of the cervical spine in healthy volunteers: a 10-year longitudinal magnetic resonance imaging study. Spine 2009;34:706–12.
7. Arana E, Marti-Bonmatí L, Mollá E, Costa S. Upper thoracic-spine disc degeneration in patients with cervical pain. Skeletal Radiol 2004;33:29–33.
8. Hassett G, Hart D, Manek N, Doyle DV, Spector TD. Risk factors for progression of lumbar spine disc degeneration: the Chingford Study. Arthritis Rheum 2003;48:3112–7.
9. Videman T, Battié MC. The influence of occupation on lumbar degeneration. Spine 1999;11:1164–8.
10. Battié MC, Videman T, Gibbons L, Manninen H, Gill K, Pope M, *et al.* Occupational driving and lumbar disc degeneration: a case control study. Lancet 2002;360:1369–74.
11. Videman T, Nurminen M, Troup JD. 1990 Volvo Award in clinical sciences. Lumbar spinal pathology in cadaveric material in relation to history of back pain, occupation, and physical loading. Spine 1990;15:728–40.
12. Adams MA, Roughley PJ. What is intervertebral disc degeneration, and what causes it? Spine 2006;31:2151–61.
13. Matsumoto M, Fujiwara Y, Suzuki N, Nishi Y, Nakayama M, Yabe Y, *et al.* MRI of cervical intervertebral discs in asymptomatic subjects. J Bone Joint Surg Br Vol 1998;80:19–24.
14. Cheung KM, Karppinen J, Chan D, Ho DW, Song YQ, Sham P, *et al.* Prevalence and pattern of lumbar magnetic resonance imaging changes in a population study of one thousand forty-three individuals. Spine 2009;34:934–40.
15. Aizawa T, Sato T, Tanaka Y, Ozawa Y, Hoshikawa T, Ishii Y, *et al.* Thoracic myelopathy in Japan: epidemiological retrospective study in Miyagi Prefecture during 15 years. Tohoku J Exp Med 2006;210:199–208.
16. Girard CJ, Schweitzer ME, Morrison WB, Parellade JA, Carrino JA. Thoracic spine disc-related abnormalities: longitudinal MR imaging assessment. Skeletal Radiol 2004;33:216–22.
17. Mclnerney J, Ball PA. The pathophysiology of thoracic disc disease. Neurosurg Focus 2000;9:e1.
18. Yoshimura N, Muraki S, Oka H, Kawaguchi H, Nakamura K, Akune T. Cohort profile: Research on Osteoarthritis/Osteoporosis Against Disability (ROAD) study. Int J Epidemiol 2010;39:988–95.
19. Yoshimura N, Muraki S, Oka H, Mabuchi A, En-yo Y, Yoshida M, *et al.* Prevalence of knee osteoarthritis, lumbar spondylosis, and osteoporosis in Japanese men and women: the research on osteoarthritis/osteoporosis against disability study. J Bone Miner Metab 2009;27:620–8.
20. Ishimoto Y, Yoshimura N, Muraki S, Yamada H, Nagata K, Hashizume H, *et al.* Prevalence of symptomatic lumbar spinal stenosis and its association with physical performance in a population-based cohort in Japan: the Wakayama Spine Study. Osteoarthritis Cartilage 2012;20:1103–8.
21. Nagata K, Yoshimura N, Muraki S, Hashizume H, Ishimoto Y, Yamada H, *et al.* Prevalence of cervical cord compression and its association with physical performance in a population-based cohort in Japan: the Wakayama Spine Study. Spine 2012;37:1892–8.
22. Choo V. WHO reassesses appropriate body-mass index for Asian populations. Lancet 2002;360:235.
23. Muraki S, Oka H, Akune T, Mabuchi A, En-yo Y, Yoshida M, *et al.* Prevalence of radiographic lumbar spondylosis and its association with low back pain in elderly subjects of population-based cohorts: the ROAD study. Ann Rheum Dis 2009;68:1401–6.
24. Muraki S, Akune T, Oka H, En-yo Y, Yoshida M, Saika A, *et al.* Impact of knee and low back pain on health-related quality of life in Japanese women: the Research on Osteoarthritis Against Disability (ROAD). Mod Rheumatol 2010;20:444–51.
25. Muraki S, Akune T, Oka H, En-yo Y, Yoshida M, Saika A, *et al.* Health-related quality of life in subjects with low back pain

and knee pain in a population-based cohort study of Japanese men: the ROAD study. Spine 2011;36:1312–9.
26. Muraki S, Akune T, Oka H, Ishimoto Y, Nagata K, Yoshida M, *et al*. Incidence and risk factors for radiographic lumbar spondylosis and lower back pain in Japanese men and women: the ROAD study. Osteoarthritis Cartilage 2012;20:712–8.
27. Pfirrmann CW, Metzdorf A, Zanetti M, Hodler J, Boos N. Magnetic resonance classification of lumbar intervertebral disc degeneration. Spine 2001;26:1873–8.
28. Benneker LM, Heini PF, Anderson SE, Alini M, Ito K. Correlation of radiographic and MRI parameters to morphological and biochemical assessment of intervertebral disc degeneration. Eur Spine J 2005;14:27–35.
29. Battié MC, Videman T, Parent E. Lumbar disc degeneration. Epidemiology and genetic influences. Spine 2004;29:2679–90.
30. Elfering A, Semmer N, Birkhofer D, Zanetti M, Hodler J, Boos N. Risk factors for lumbar disc degeneration: a 5-year prospective MRI study in asymptomatic individuals. Spine 2001;27:125–34.
31. Luoma K, Riihimäki H, Luukkonen R, Raininko R, Viikari-Juntura E, Lamminen A. Low back pain in relation to lumbar disc degeneration. Spine 2000;25:487–92.
32. Boden SD, Davis DO, Dina TS, Patronas NJ, Wiesel SW. Abnormal magnetic-resonance scans of the lumbar spine in asymptomatic subjects: a prospective investigation. J Bone Joint Surg Am Vol 1990;72:403–8.
33. Hanagai M, Kaneoke K, Kuno S, Hinotsu S, Sakane M, Mamizuka N, *et al*. Factors associated with lumbar intervertebral disc degeneration in the elderly. Spine J 2008;8:732–40.
34. Kanayama M, Togawa D, Takahashi C, Terai T, Hashimoto T. Cross-sectional magnetic resonance imaging study of lumbar disc degeneration in 200 healthy individuals. J Neurosurg Spine 2009;11:501–7.
35. Matsumoto M, Okada E, Ichihara D, Watanabe K, Chiba K, Toyama Y, *et al*. Age-related changes of thoracic and cervical intervertebral discs in asymptomatic subjects. Spine 2010;35:1359–64.
36. Lee CS, Chung SS, Kang KC, Park SJ, Shin SK. Normal patterns of sagittal alignment of the spine in young adults radiological analysis in a Korean population. Spine 2011;36:1648–54.
37. Keller T, Colloca CJ, Harrison DE, Harrison DD, Janik TJ. Influence of spine morphology on intervertebral disc loads and stresses in asymptomatic adults: implications for the ideal spine. Spine J 2005;5:297–309.
38. An HS, Wise JJ, Xu R. Anatomy of the cervicothoracic junction: a study of cadaveric dissection, cryomicrotomy and magnetic resonance imaging. J Spinal Disord 1999;12:519–25.
39. Samartzis D, Karppinen J, Chan D, Luk KD, Cheung KM. The association of lumbar intervertebral disc degeneration on magnetic resonance imaging with body mass index in overweight and obese adults. Arthritis Rheum 2012;64:1488–96.
40. Miller JA, Schmatz C, Schultz AB. Lumbar disc degeneration: correlation with age, sex, and spine level in 600 autopsy specimens. Spine 1988;13:173–8.
41. Wang YX, Griffith JF, Ma HT, Kwok AW, Leung JC, Yeung DK, *et al*. Relationship between gender, bone mineral density, and disc degeneration in the lumbar spine: a study in elderly subjects using an eight-level MRI-based disc degeneration grading system. Osteoporos Int 2011;22:91–6.
42. Battié MC, Videman T, Gill K, Moneta GB, Nyman R, Kaprio J, *et al*. 1991 Volvo Award in clinical sciences. Smoking and lumbar intervertebral disc degeneration: an MRI study of identical twins. Spine 1991;16:1015–21.
43. Battié MC, Videman T, Kaprio J, Gibbons LE, Gill K, Manninen H, *et al*. The Twin Spine Study: contributions to a changing view of disc degeneration. Spine J 2009;9:47–59.
44. Ministry of Health, Labour and Welfare. The Outline of the Results of National Livelihood Survey. Available at: http://www.mhlw.go.jp/toukei/list/20-19-1.html; 2007.

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The Spine Journal ■ (2015) ■

THE SPINE JOURNAL

Clinical Study

The association of combination of disc degeneration, end plate signal change, and Schmorl node with low back pain in a large population study: the Wakayama Spine Study

Masatoshi Teraguchi, MD, PhD[a], Noriko Yoshimura, MD, PhD[b], Hiroshi Hashizume, MD, PhD[a,*], Shigeyuki Muraki, MD, PhD[c], Hiroshi Yamada, MD, PhD[a], Hiroyuki Oka, MD[b], Akihito Minamide, MD, PhD[a], Hiroyuki Nakagawa, MD, PhD[a], Yuyu Ishimoto, MD, PhD[a], Keiji Nagata, MD, PhD[a], Ryohei Kagotani, MD, PhD[a], Sakae Tanaka, MD, PhD[d], Hiroshi Kawaguchi, MD, PhD[e], Kozo Nakamura, MD, PhD[f], Toru Akune, MD, PhD[b], Munehito Yoshida, MD, PhD[a]

[a]*Department of Orthopaedic Surgery, Wakayama Medical University, 811-1 Kimiidera, Wakayama City, Wakayama 641-8510, Japan*

[b]*Department of Joint Disease Research, 22nd Century Medical and Research Center, Faculty of Medicine, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8655, Japan*

[c]*Department of Clinical Motor System Medicine, 22nd Century Medical and Research Center, Faculty of Medicine, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8655, Japan*

[d]*Department of Orthopaedic Surgery, Faculty of Medicine, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8655, Japan*

[e]*Japan Community Health Care Organization Tokyo Shinjuku Medical Center, 6-1-1 Shinjuku, Shinjuku-ku, Tokyo 160-8402, Japan*

[f]*Rehabilitation Services Bureau, National Rehabilitation Center for Persons with Disabilities, 1 Namiki 4-chome, Tokorozawa City, Saitama 359-8555, Japan*

Received 17 July 2014; revised 21 October 2014; accepted 20 November 2014

Abstract

BACKGROUND CONTEXT: Disc degeneration (DD) reportedly causes low back pain (LBP) and is often observed concomitantly with end plate signal change (ESC) and/or Schmorl node (SN) on magnetic resonance imaging.

PURPOSE: The purpose of this study was to examine the association between DD and LBP, considering ESC and/or SN presence, in a large population study.

STUDY DESIGN/SETTING: Cross-sectional population-based study in two regions of Japan.

PATIENT SAMPLE: Of 1,011 possible participants, data from 975 participants (324 men, 651 women; mean age, 66.4 years; range, 21–97 years) were included.

OUTCOME MEASURES: Prevalence of DD, ESC, and SN alone and in combination in the lumbar region and the association of these prevalence levels with LBP.

METHODS: Sagittal T2-weighted images were used to assess the intervertebral spaces between L1–L2 and L5–S1. Disc degeneration was classified using the Pfirrmann classification system (grades 4 and 5 indicated degeneration); ESC was defined as a diffuse high signal change along

FDA device/drug status: Not applicable.

Author disclosures: ***MT:*** Grant: Grant-in-Aid for Young Scientists, B26861206 (D, Paid directly to institution). ***NY:*** Grant: Grant-in-Aid for Scientific Research, B26293139 (F, Paid directly to institution) and Grant-in-Aid for Challenging Exploratory Research, 24659317 (D, Paid directly to institution). ***HH:*** Grant: Grant-in-Aid for Scientific Research, C26462249 (D, Paid directly to institution). ***SM:*** Grant: Grant-in-Aid for Scientific Research, B23390356 (F, Paid directly to institution). ***HY:*** Grant: Grant-in-Aid for Scientific Research, C25462305 (D, Paid directly to institution). ***HO:*** Grant: Grant-in-Aid for Challenging Exploratory Research, 24659666 (D, Paid directly to institution). ***AM:*** Nothing to disclose. ***HN:*** Nothing to disclose. ***YI:*** Grant: Grant-in-Aid for Young Scientists, B25860448 (D, Paid directly to institution). ***KNag:*** Nothing to disclose. ***RK:*** Grant: Grant-in-Aid for Young Scientists, B26860419 (D, Paid directly to institution). ***ST:*** Nothing to disclose. ***HK:*** Nothing to disclose. ***KNak:*** Nothing to disclose. ***TA:*** Grant: Grant-in-Aid for Challenging Exploratory Research, 25670293 (D, Paid directly to institution). ***MY:*** Grant: Health Labour Sciences Research Grant, H20-Choju-Ippan-009 (D, Paid directly to institution).

The disclosure key can be found on the Table of Contents and at www.TheSpineJournalOnline.com.

This study was funded by the Ministry of Education, Culture, Sports, Science and Technology, and the Ministry of Health, Labour and Welfare in Japan. The sponsors did not contribute to the study design, data collection, data analysis, data interpretation, or the writing of the manuscript.

* Corresponding author. Department of Orthopedic Surgery, Wakayama Medical University, 811-1 Kimiidera, Wakayama City, Wakayama 641-8510, Japan. Tel.: +81-73-441-0645; Fax: +81-73-448-3008.

E-mail address: hashizum@wakayama-med.ac.jp (H. Hashizume)

http://dx.doi.org/10.1016/j.spinee.2014.11.012

either area of the end plate, and SN was defined as a small well-defined herniation pit with a surrounding wall of hypointense signal. Logistic regression analysis was used to determine the odds ratios (ORs) and confidence intervals (CIs) for LBP in the presence of radiographic changes in the lumbar region and at each lumbar intervertebral level, compared with patients without radiographic change, after adjusting for age, body mass index, and sex.

RESULTS: The prevalence of lumbar structural findings was as follows: DD alone, 30.4%; ESC alone, 0.8%; SN alone, 1.5%; DD and ESC, 26.6%; DD and SN, 12.3%; and DD, ESC, and SN, 19.1%. These lumbar structural findings were significantly associated with LBP in the lumbar region overall, as follows: DD, ESC, and SN, OR 2.17, 95% CI 1.2–3.9; L1–L2, OR 6.00, 95% CI 1.9–26.6; L4–L5, OR 2.56, 95% CI 1.4–4.9; and L5–S1, OR 2.81, 95% CI 1.1–2.3. The combination of DD and ESC was significantly associated with LBP as follows: L3–L4, OR 2.43, 95% CI 1.5–4.0; L4–L5, OR 1.82, 95% CI 1.2–2.8; and L5–S1, OR 1.60, 95% CI 1.1–2.3.

CONCLUSIONS: Our data suggest that DD alone is not associated with LBP. By contrast, the combination of DD and ESC was highly associated with LBP.

Keywords: Disc degeneration; End plate signal change; Schmorl node; Low back pain; Large population study; ROAD study

Introduction

Low back pain (LBP) causes functional impairment, diminished quality of life, loss of working ability, potential psychological distress, and increased health-care costs [1–3]. Magnetic resonance imaging (MRI) has become widely used in LBP diagnosis [4–15].

From the perspective of discogenic pain, the association between disc degeneration (DD) and symptoms remains controversial. Several reports have found that DD was a source of LBP [4–7], but others reported no association between DD and LBP [8,9]. This discrepancy is partly explained by the fact that DD often occurs concomitantly with various radiographic changes such as end plate signal change (ESC) and Schmorl node (SN). However, few studies have reported on the association of ESC and SN with LBP [10–14], and furthermore, to the best of our knowledge, no population-based study has examined the association of the combination of DD, ESC, and SN with LBP.

The purposes of this study were to examine the prevalence of combinations of DD, ESC, and SN in the lumbar region overall and to clarify the associations between LBP and combinations of DD, ESC, and SN in a large population.

Methods

Participants

The Wakayama Spine Study is a population-based study of degenerative spinal disease [15–17] performed in a subcohort of the large-scale population-based cohort study Research on Osteoarthritis/Osteoporosis against Disability (ROAD) [18,19]. Research on Osteoarthritis/Osteoporosis against Disability is a nationwide prospective study of bone and joint diseases consisting of population-based cohorts established in three communities in Japan. The participants were recruited from listings of resident registrations in three communities that have different characteristics: an urban region in Itabashi, Tokyo; a mountainous region in Hidakagawa, Wakayama; and a coastal region in Taiji, Wakayama. The inclusion criteria, apart from residence in the communities mentioned previously, were the ability to walk to the survey site, report data, and understand and sign an informed consent form. The age of the participants recruited from the urban region was 60 years or older and that of the participants from the other two regions was 40 years or older [18]. A second visit of the ROAD study to the mountainous region of Hidakagawa and the coastal region of Taiji was performed between 2008 and 2010. From the inhabitants participating in the second visit of the ROAD study, 1,063 volunteers were recruited to MRI examinations. Among these volunteers, 52 declined to attend the examination and 1,011 provided an additional written informed consent for the mobile MRI examination and were recruited for registration in the Wakayama Spine Study. Among the 1,011 participants, those who had an MRI-sensitive implanted device (e.g., pacemaker) or other disqualifier were excluded. Ultimately, 980 individuals underwent whole-spine MRI. One participant who had undergone a previous cervical operation and four participants who had undergone previous posterior lumbar fusion were excluded from the analysis. Thus, whole-spine MRI results were available for 975 participants (324 men and 651 women) with an age range of 21 to 97 years (mean, 67.2 years for men and 66.0 years for women). Experienced board-certified orthopedic surgeons also asked all participants the following question regarding LBP: ‘‘Have you experienced LBP on most days during the past month, in addition to now?’’ Those who answered ‘‘yes’’ were defined as having LBP based on the previous studies [20–24]. All study participants provided informed consent, and the study design was approved by the appropriate ethics review boards.

Magnetic resonance imaging

A mobile MRI unit (Excelart 1.5 T; Toshiba, Tokyo, Japan) was used, and whole-spine MRI was performed for all participants on the same day as the examination. The participants were supine during the MRI, and those with rounded backs used triangular pillows under their head and knees. The imaging protocol included sagittal T2-weighted fast spin echo (repetition time, 4,000 ms/echo; echo time, 120 ms; and field of view, 300×320 mm) and axial T2-weighted fast spin echo (repetition time, 4,000 ms/echo; echo time, 120 ms; and field of view, 180×180 mm). Sagittal T1-weighted images were omitted owing to cost and time limitations; only T2-weighted images were obtained.

Radiographic assessment

Sagittal T2-weighted images were used to assess DD, ESC, and SN at all intervertebral levels from C2–C3 to L5–S1. The present study assessed L1–L2 to L5–S1 in the lumbar region.

Disc degeneration

Disc degeneration grading was performed by a board-certified orthopedic surgeon who was blinded to the background of the participants. The degree of DD on MRI was classified into five grades based on the Pfirrmann classification system [25], with grades 4 and 5 indicating DD. To evaluate intraobserver variability, 100 randomly selected MR images of the entire spine were rescored by the same observer more than 1 month after the first reading. Furthermore, to evaluate interobserver variability, 100 other MR images were scored by 2 orthopedic surgeons using the same classification. The intraobserver and interobserver variabilities of DD, as evaluated by kappa analysis, were 0.94 and 0.94, respectively.

End plate signal change

End plate signal change was defined as diffuse areas of high signal change along the end plates, tending to be linear and always parallel to the vertebral end plates on sagittal T2-weighted images. However, discerning the type of Modic changes [26,27] was not possible because of cost and time limitations of this large-scale study. Because the T1 sequence was not obtained, we considered Modic Type I/II (T2 high signal intensity end plate change) to reflect the presence of ESC and T2 isosignal intensity and Modic Type III (T2 low signal intensity end plate change) to reflect the absence of ESC. To evaluate the intraobserver and interobserver variabilities, two orthopedic surgeons scored MR images in the same manner. The intraobserver and interobserver variabilities of ESC evaluated by kappa analysis were 0.86 and 0.82, respectively.

Schmorl node

Schmorl node was characterized by a localized defect at the rostral, caudal, or both end plates, with a well-defined herniation pit in the vertebral body with or without a surrounding sclerotic rim (low signal on T2-weighted image) [14,28]. Erosive defects in the end plate in degenerate segments were not considered as SN [14,28]. To evaluate intraobserver and interobserver variabilities, two orthopedic surgeons scored MR images in the same manner. The intraobserver and interobserver variabilities for SN evaluated by kappa analysis were 0.92 and 0.84, respectively.

Statistical analyses

Radiographic changes were compared between sexes using the chi-square test. Multivariate logistic regression analysis was used to estimate the radiographic changes of DD, ESC, and SN presence in the lumbar region as dependent variables, with LBP as the independent variable, after adjustment for age, body mass index (BMI), and sex. Multivariate logistic regression analysis was used to estimate the respective associations of eight combinations of radiographic changes (none; DD alone; SN alone; ESC alone; DD and SN; DD and ESC; SN and ESC; and DD, ESC, and SN) in the lumbar region as dependent variables, with LBP as the independent variable, after adjustment for age, BMI, and sex. Multivariate logistic regression analysis was also used to estimate the association of 8 combinations of radiographic changes at each intervertebral level (L1–L2 to L5–S1) in the lumbar region after adjustment for age, BMI, and sex. All statistical analyses were performed using JMP, version 8 (SAS Institute Japan, Tokyo, Japan).

Prevalence of DD, ESC, and/or SN, defined as the proportion of the number of participants who demonstrated the presence of DD, ESC, and/or SN in the lumbar region divided by the total number of participants, was used to describe the frequency of DD, ESC, and/or SN. In this analysis, to clarify the associated factors using multivariate logistic regression analysis, we entered a variable reflecting the observation of DD, ESC, and/or SN (1, presence; 0, absence) as a dependent variable.

Table 1
Characteristics of the 975 participants in the present study

	Overall	Men	Women
No. of participants	975	324	651
Demographic characteristics			
Age, y	66.4±13.5	67.2±13.9	66.0±13.4
Height, cm	156.4±9.4	164.6±7.2	151.5±7.2
Weight, kg	56.8±11.5	64.5±11.6	53.0±9.4
BMI, kg/m^2	23.3±3.6	23.6±3.4	23.1±3.7
Symptom			
LBP (%)	393 (40.3)	119 (36.7)	274 (42.1)

BMI, body mass index; LBP, low back pain.
Note: Values are the mean±standard deviation.

Table 2
Prevalence of combination of radiographic change in the lumbar region according to sex

	Overall (%)	Men (%)	Women (%)
Total	975	324	651
None	85 (8.7)	35 (10.8)	50 (7.7)
DD alone	296 (30.4)	104 (32.1)	192 (29.5)
ESC alone	8 (0.8)	3 (0.9)	5 (0.8)
SN alone	15 (1.5)	6 (1.9)	9 (1.4)
DD and ESC	259 (26.6)	85 (26.2)	174 (26.7)
DD and SN	120 (12.3)	37 (11.4)	83 (12.8)
SN and ESC	6 (0.6)	0 (0)	6 (0.9)
DD, ESC, and SN	186 (19.1)	54 (16.7)	132 (20.3)

DD, disc degeneration; ESC, end plate signal change; SN, Schmorl node.

Note: Chi-square test was used to determine differences in radiographic change between men and women.

Table 3
Association between LBP and radiographic changes in the lumbar region

	Proportion of participants with LBP (%)	OR (95% CI)
None	25/85 (29.4)	1
DD alone	112/296 (37.8)	1.35 (0.8–2.3)
ESC alone	0/8 (0)	—
SN alone	5/15 (33.3)	1.14 (0.3–3.6)
DD and ESC	107/259 (41.3)	1.51 (0.9–2.6)
DD and SN	45/120 (37.5)	1.26 (0.7–2.3)
SN and ESC	3/6 (50.0)	2.06 (0.4–11.9)
DD, ESC, and SN	96/186 (51.6)	2.17 (1.2–3.9)*

CI, confidence interval; DD, disc degeneration; ESC, end plate signal change; LBP, low back pain; OR, odds ratio; SN, Schmorl node.

Note: Proportion of participants with LBP means the number of participants with LBP/the number of participants with each radiographic change. ORs were calculated by multivariate logistic regression analysis after adjustment for age, body mass index, and sex.

* $p<.01$.

Results

Table 1 shows the characteristics of the 975 participants in the present study including age and demographic measurements. Two-thirds of the participants were women.

The prevalence of DD, ESC, and SN in the lumbar region overall, without considering other radiographic changes, was 86.7%, 44.1%, and 29.6% in men and 89.6%, 48.7%, and 35.2% in women, respectively. Table 2 shows the prevalence of combinations of radiographic changes according to sex. DD alone demonstrated the highest prevalence, followed by DD and ESC and DD, ESC, and SN in both sexes. The prevalence of SN alone, ESC alone, or the combination of SN and ESC was small. The prevalence of combinations of radiographic changes in the lumbar region did not significantly differ between men and women.

When we evaluated DD, ESC, and SN in the lumbar region overall without considering other radiographic change, DD presence and ESC presence in the lumbar region were each significantly associated with LBP (DD: odds ratio [OR] 1.58, 95% confidence interval [CI] 1.02–2.49; ESC: OR 1.36, 95% CI 1.04–1.76). On the other hand, SN presence in the lumbar region was not significantly associated with LBP (OR 1.27, 95% CI 0.96–1.68). Next, to determine the effect of the combination of DD, ESC, and SN on LBP, we classified participants into eight groups: none; DD alone; ESC alone; SN alone; DD and ESC; DD and SN; SN and ESC; and DD, ESC, and SN. As shown in Table 3, the combination of DD, ESC, and SN in the lumbar region was significantly associated with LBP. Disc degeneration alone was not an associated factor for LBP.

Furthermore, as shown in Table 4, the effect of combinations of radiographic change at each intervertebral level from L1–L2 to L5–S1 on LBP was evaluated: the combination of DD, ESC, and SN was significantly associated with LBP at L1–L2, L4–L5, and L5–S1. Furthermore, the combination of DD and ESC was significantly associated with LBP at L3–L4, L4–L5, and L5–S1.

Discussion

The prevalence of DD, ESC, or SN in the lumbar region has been examined in some previous studies [11–15,26–32], but, to the authors' knowledge, no population-based studies have assessed the prevalence of the combination of DD, ESC, and SN in a large population using MRI. First, we found that prevalence of combinations of DD, ESC, and SN in the lumbar region was approximately 20%. By contrast, the prevalence of ESC alone, SN alone, and combination of SN and ESC was quite small, which is partly explained by the fact that DD was reported to have a strong positive linear relationship with ESC and/or SN in the previous studies [14,28,33].

The association of DD with LBP remains controversial. An association between DD in the lumbar region and LBP was previously demonstrated in a twin study and other previous studies [15,30,31]. However, some reports have observed a high prevalence of DD among asymptomatic volunteers, with no association between DD and LBP [8,9]. These studies may have been limited in that they did not account for interactions between radiographic changes including DD, ESC, and SN. The present study found that the combination of DD, ESC, and SN was significantly associated with LBP, whereas DD alone was not.

The association of Modic changes, which are the gold standard to diagnose ESC, with clinical symptoms, has been controversial in the clinical studies based on patient series and a population-based cohort [10–12,29,32]. The present study found that the combination of DD and ESC at L3–L4, L4–L5, and L5–S1 was significantly associated with LBP. Degenerative change of end plates becomes a source of LBP and affects DD. Because the lumbar vertebral end plate contains immunoreactive nerves, as shown in the studies of sheep and humans [33,34], it has been reported that an increased number of tumor necrosis factor–immunoreactive spinal nerve cells and fibers are present in end plates

Table 4
Association between LBP and radiographic changes at each level in the lumbar region

	L1–L2		L2–L3		L3–L4		L4–L5		L5–S1	
	Proportion of participants with LBP (%)	OR (95% CI)	Proportion of participants with LBP (%)	OR (95% CI)	Proportion of participants with LBP (%)	OR (95% CI)	Proportion of participants with LBP (%)	OR (95% CI)	Proportion of participants with LBP (%)	OR (95% CI)
None	225/593 (37.9)	1	153/416 (36.8)	1	121/347 (34.9)	1	74/228 (32.5)	1	99/284 (34.9)	1
DD alone	76/193 (39.4)	1.0 (0.7–1.4)	138/322 (42.9)	1.19 (0.9–1.6)	161/400 (40.3)	1.17 (0.9–1.6)	184/449 (41.0)	1.36 (0.9–1.9)	176/440 (40.0)	1.14 (0.8–1.6)
ESC alone	11/27 (40.7)	1.06 (0.5–2.3)	9/23 (39.1)	0.96 (0.4–2.3)	3/10 (30.0)	0.74 (0.2–2.7)	3/16 (18.8)	0.50 (0.1–1.6)	6/15 (40.0)	1.24 (0.4–3.6)
SN alone	19/46 (41.3)	1.07 (0.6–2.0)	15/40 (37.5)	1.03 (0.5–2.0)	10/22 (45.5)	1.58 (0.6–3.8)	5/14 (35.7)	1.18 (0.3–3.5)	1/1 (100)	—
DD and ESC	16/36 (44.4)	1.20 (0.6–2.4)	33/69 (47.8)	1.37 (0.8–2.3)	55/93 (59.1)	2.43 (1.5–4.0)*	81/164 (49.4)	1.82 (1.2–2.8)†	96/201 (47.8)	1.60 (1.1–2.3)*
DD and SN	31/61 (50.8)	1.47 (0.8–2.6)	32/73 (43.8)	1.14 (0.7–1.9)	24/70 (34.3)	0.84 (0.5–1.5)	16/52 (30.8)	0.84 (0.4–1.6)	3/15 (20.0)	0.45 (0.1–1.5)
SN and ESC	2/3 (66.7)	2.48 (0.2–53.8)	0/6 (0)	—	2/2 (100)	—	1/2 (50.0)	2.04 (0.08–52.5)	0/0 (0)	—
DD, ESC, and SN	13/16 (81.3)	6.00 (1.9–26.6)‡	13/26 (50.0)	1.49 (0.7–3.4)	17/31 (54.8)	2.07 (0.9–4.5)	29/50 (58.0)	2.56 (1.4–4.9)‡	12/19 (63.2)	2.85 (1.1–2.3)*

CI, confidential interval; DD, disc degeneration; ESC, end plate signal change; LBP, low back pain; OR, odds ratio; SN, Schmorl node.
Note: Proportion of participants with LBP means the number of participants with LBP/the number of participants with each radiographic change. Multivariate logistic regression analysis of radiographic change was associated with LBP after adjustment for age, body mass index, and sex.
* $p<.05$.
† $p<.01$.
‡ $p<.005$.

demonstrating ESC [35]. Therefore, pain may originate from damaged end plates in patients with ESC.

Another possibility is that ESC is a proxy for discogenic pain, as ESC is most often seen in association with DD [12,36] and tumor necrosis factor–immunoreactive nerves have also been reported in DD [37]. Both the present results and a previous study indicate that the association between ESC and LBP appears to be stronger than that between DD and LBP [29]. Regarding the association between the level of ESC and LBP, Kuisma et al. [32] reported that both Modic type I and II lesions at L5–S1, but not at upper levels, are associated with LBP. However, the present study showed that the OR of LBP with Modic type I and II lesions at L3–L4 was higher than that at L5–S1. We speculate that the association of LBP symptoms with the L3–L4 level might be because of mechanical factors and alignment of the whole spine, but the pathophysiology of this phenomenon needs further investigation.

In the present study, SN alone was not significantly associated with LBP. In addition, most SNs were combined with DD. In fact, SN was not itself a risk factor for back pain but was an indicator of DD in the previous reports [13,14,28]. Furthermore, SN occurs when the cartilaginous end plate of the vertebral body has been disrupted [38]. Such a disruption can be produced by an intrinsic abnormality of the end plate itself or by alterations in the subchondral bone of the vertebral body [39]. Therefore, LBP might be a multifactorial condition arising from a combination of DD, ESC, and SN in the lumbar region.

Study limitations

The present study has several limitations. First, it is a cross-sectional study, so the transition from DD, ESC, and SN cannot be clarified. Second, more than 1,000 participants included in the present study may not represent the general population, as they were recruited from only 2 areas. To confirm whether the participants of the Wakayama Spine Study are representatives of the Japanese population, we compared anthropometric measurements and frequencies of smoking and alcohol drinking between the study participants and the general Japanese population. No significant differences in BMI were observed (men: 23.7 and 24.0, $p=.33$ and women: 23.1 and 23.5, $p=.07$). Furthermore, the proportions of current smokers and drinkers (those who regularly smoked or drank more than one drink per month) among men and that of current drinkers among women were significantly higher in the general Japanese population than in the study population, and no significant difference in current smokers was observed among women (men smokers, 32.6% in the Japanese population and 25.2% among study participants, $p=.015$; women smokers, 4.9% in the Japanese population and 4.1% among study participants, $p=.50$; men drinkers, 73.9% in the Japanese population and 56.8% among study participants, $p<.0001$; and women drinkers, 28.1% in the Japanese population and 18.8% among study participants,

$p<.0001$). These results suggest the likelihood that participants in this study had healthier lifestyles than the general Japanese population [40]. This ‘‘healthy’’ selection bias should be taken into consideration when generalizing the results obtained from the Wakayama Spine Study. Third, distinction of the type of Modic changes was not possible because owing to cost and time limitations, only T2-weighted images were obtained. However, Ohtori et al. [35] reported that both Modic type I and II changes were significantly associated with inflammation induced by tumor necrosis factor. Furthermore, the prevalence of Modic Type I was lower than that of Type II in a systematic review [41]. Therefore, we propose that high-intensity ESC on T2-weighted images is informative in the assessment of LBP. Fourth, the definition of LBP is different among many studies [24,32], and the result of association between LBP and radiographic change might be changed depending on the definition. We decided that the definition of LBP was ‘‘LBP on most days during the past month, in addition to now’’ from the previous reports [20–24].

Finally, the radiographic changes of DD, ESC, and SN in the lumbar region might not be strongly correlated with LBP. Low back pain can be caused by multiple factors including osteoporosis, back muscle strain, and psychosocial problems; thus, we can explain only a portion of the associated factors of LBP from MRI findings. Future investigations should include continued follow-up surveys of psychosocial and other factors.

Conclusions

We first investigated combinations of the radiographic changes DD, ESC, and SN in the lumbar region and at each intervertebral level and their association with LBP in a large population of individuals ranging in age from 21 to 97 years old. Our data suggest that DD alone is not an associated factor for LBP. By contrast, the combination of DD, ESC, and SN at L1–L2, L4–L5, and L5–S1 was significantly associated with LBP. Furthermore, the combination of DD and ESC at L3–L4, L4–L5, and L5–S1 was also significantly associated with LBP. Low back pain is caused by multiple factors beyond the scope of MRI findings. However, this study clarified that DD alone was not associated with LBP, whereas, by contrast, the combination of DD, ESC, and/or SN was associated with LBP. Although they may not be immediately applicable to clinical practice, these findings contribute to the progress of LBP research. Further investigations along with continued follow-up surveys will continue to elucidate the causes of LBP.

Acknowledgements

The authors wish to thank Mrs Tomoko Takijiri and other members of the Public Office in Hidakagawa Town and Mrs Tamako Tsutsumi, Mrs Kanami Maeda, and other members of the Public Office in Taiji Town for their assistance in the location and scheduling of participants for examinations. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

References

[1] Dagenais S, Caro J, Haldeman S. A systematic review of low back pain cost of illness studies in the United States and internationally. Spine J 2008;8:8–20.

[2] Deyo RA, Tsui-Wu YJ. Descriptive epidemiology of low-back pain and its related medical care in the United States. Spine 1987;12:264–8.

[3] Andersson GB. Epidemiological features of chronic low-back pain. Lancet 1999;354:581–5.

[4] Luoma K, Riihimaki H, Luukkonen R, Raininko R, Viikari-Juntura E, Lamminen A. Low back pain in relation to lumbar disc degeneration. Spine 2000;25:487–92.

[5] Chou D, Samartzis D, Bellabarba C, Patel A, Luk KD, Kisser JM, et al. Degenerative magnetic resonance imaging changes in patients with chronic low back pain: a systematic review. Spine 2011;36:S43–53.

[6] Takatalo J, Karppinen J, Niinimaki J, Taimela S, Nayha S, Mutanen P, et al. Does lumbar disc degeneration on magnetic resonance imaging associate with low back symptom severity in young Finnish adults? Spine 2011;36:2180–9.

[7] Carragee E, Alamin T, Cheng I, Franklin T, van den Haak E, Hurwitz E. Are first-time episodes of serious LBP associated with new MRI findings? Spine J 2006;6:624–35.

[8] Boden SD, Davis DO, Dina TS, Patronas NJ, Wiesel SW. Abnormal magnetic-resonance scans of the lumbar spine in asymptomatic subjects: a prospective investigation. J Bone Joint Surg Am 1990;72:403e8.

[9] Jensen MC, Brant-Zawadzki MN, Obuchowski N, Modic MT, Malkasian D, Ross JS. Magnetic resonance imaging of the lumbar spine in people without back pain. N Engl J Med 1994;331:69–73.

[10] Weishaupt D, Zanetti M, Hodler J, Min K, Fuchs B, Pfirrmann CW, et al. Painful lumbar disc derangement: relevance of endplate abnormalities at MR imaging. Radiology 2001;218:420–7.

[11] Mitra D, Cassar-Pullicino VN, McCall IW. Longitudinal study of vertebral type-1 end-plate changes on MR of the lumbar spine. Eur Radiol 2004;24:1574–81.

[12] Toyone T, Takahashi K, Kitahara H, Yamagata M, Murakami M, Moriya H. Vertebral bone-marrow changes in degenerative lumbar disc disease. An MRI study of 74 patients with low back pain. J. Bone Joint Surg Br 1994;76:757–64.

[13] Kjaer P, Leboeuf-Yde C, Korsholm L, Sorensen JS, Bendix T. Magnetic resonance imaging and low back pain in adults: a diagnostic imaging study of 40-year-old men and women. Spine 2005;30:1173–80.

[14] Williams FMK, Manek NJ, Sambrook PN, Spector TD, Macgregor AJ. Schmorl's nodes: common, highly heritable, and related to lumbar disc disease. Arthritis Rheum 2007;57:855–60.

[15] Teraguchi M, Yoshimura N, Hashizume H, Muraki S, Yamada H, Minamide A, et al. Prevalence and distribution of intervertebral disc degeneration over the entire spine in a population-based cohort: the Wakayama Spine Study. Osteoarthritis Cartilage 2014;22:104–10.

[16] Ishimoto Y, Yoshimura N, Muraki S, Yamada H, Nagata K, Hashizume H, et al. Prevalence of symptomatic lumbar spinal stenosis and its association with physical performance in a population-based cohort in Japan: the Wakayama Spine Study. Osteoarthritis Cartilage 2012;20:1103–8.

[17] Nagata K, Yoshimura N, Muraki S, Hashizume H, Ishimoto Y, Yamada H, et al. Prevalence of cervical cord compression and its association with physical performance in a population-based cohort in Japan: the Wakayama Spine Study. Spine 2012;37:1892–8.

[18] Yoshimura N, Muraki S, Oka H, Kawaguchi H, Nakamura K, Akune T. Cohort profile: research on osteoarthritis/osteoporosis against disability (ROAD) study. Int J Epidemiol 2010;39:988–95.
[19] Yoshimura N, Muraki S, Oka H, Mabuchi A, En-Yo Y, Yoshida M, et al. Prevalence of knee osteoarthritis, lumbar spondylosis, and osteoporosis in Japanese men and women: the research on osteoarthritis/osteoporosis against disability study. J Bone Miner Metab 2009;27:620–8.
[20] Muraki S, Oka H, Akune T, Mabuchi A, En-Yo Y, Yoshida M, et al. Prevalence of radiographic lumbar spondylosis and its association with low back pain in elderly subjects of population-based cohorts: the ROAD study. Ann Rheum Dis 2009;68:1401–6.
[21] Muraki S, Akune T, Oka H, En-Yo Y, Yoshida M, Saika A, et al. Impact of knee and low back pain on health-related quality of life in Japanese women: the Research on Osteoarthritis against Disability (ROAD). Mod Rheumatol 2010;20:444–51.
[22] Muraki S, Akune T, Oka H, En-Yo Y, Yoshida M, Saika A, et al. Health-related quality of life in subjects with low back pain and knee pain in a population-based cohort study of Japanese men: the ROAD study. Spine 2011;36:1312–9.
[23] Muraki S, Akune T, Oka H, Ishimoto Y, Nagata K, Yoshida M, et al. Incidence and risk factors for radiographic lumbar spondylosis and lower back pain in Japanese men and women: the ROAD study. Osteoarthritis Cartilage 2012;20:712–8.
[24] Dionne CE, Dunn KM, Croft PR, Nachemson AL, Bunchbinder R, Walker BF, et al. A consensus approach toward the standardization of back pain definitions for use in prevalence studies. Spine 2008;33:95–103.
[25] Pfirrmann CW, Metzdorf A, Zanetti M, Hodler J, Boos N. Magnetic resonance classification of lumbar intervertebral disc degeneration. Spine 2001;26:1873–8.
[26] Modic MT, Steinberg PM, Ross JS, Masaryk TJ, Carter JR. Degenerative disc disease: assessment of changes in vertebral body marrow with MR imaging. Radiology 1988;166:193–9.
[27] Modic MT, Masaryk TJ, Ross JS, Carter JR. Imaging of degenerative disc disease. Radiology 1988;168:177–86.
[28] Mok FP, Samartzis D, Karppinen J, Luk KD, Fong DY, Cheung KM. ISSLS prize winner: prevalence, determinants, and association of Schmorl's nodes of the lumbar spine with disc degeneration: a population-based study of 2449 individuals. Spine 2010;35:1944–52.
[29] Kjaer P, Korsholm L, Bendix T, Sorensen JS, Leboeuf-Yde C. Modic changes and their associations with clinical finding. Eur Spine J 2006;15:1312–9.
[30] Battié MC, Videman T, Kaprio J, Gibbons LE, Gill K, Manninen H, et al. The Twin Spine Study: contributions to a changing view of disc degeneration. Spine J 2009;9:47–59.
[31] Cheung KM, Karppinen J, Chan D, Ho DW, Song YQ, Sham P, et al. Prevalence and pattern of lumbar magnetic resonance imaging changes in a population study of one thousand forty-three individuals. Spine 2009;34:934–40.
[32] Kuisma M, Karppinen J, Niinimaki J, Ojala R, Haapea M, Heliovaara M, et al. Modic changes in endplates of lumbar vertebral bodies: prevalence and association with low back and sciatic pain among middle-aged male workers. Spine 2007;32:1116–22.
[33] Rajasekaran S, Babu JN, Arun R, Armstrong BR, Shetty AP, Murugan S. ISSLS prize winner: a study of diffusion in human lumbar discs: a serial magnetic resonance imaging study documenting the influence of the endplate on diffusion in normal and degenerate discs. Spine 2004;29:2654–67.
[34] Brown MF, Hukkanen MV, McCarthy ID, Redfern DR, Batten JJ, Crock HV, et al. Sensory and sympathetic innervation of the vertebral endplate in patients with degenerative disc disease. J Bone Joint Surg Br 1997;79:147–53.
[35] Ohtori S, Inoue G, Ito T, Koshi T, Ozawa T, Doya H, et al. Tumor necrosis factor-immunoreactive cells and PGP 9.5-immunoreactive nerve fibers in vertebral endplates of patients with discogenic low back pain and Modic type 1 or type 2 changes on MRI. Spine 2006;31:1026–31.
[36] Albert HB, Manniche C. Modic changes following lumbar disc herniation. Eur Spine J 2007;16:977–82.
[37] Freemont AJ, Peacock TE, Goupille P, Hoyland JA, O'Brien J, Jayson MI. Nerve ingrowth into diseased intervertebral disc in chronic back pain. Lancet 1997;350:178–81.
[38] Schmorl G. Uber Knorpelknotchen an den Wirbelbandscheiben (About cartilaginous node of the intervertebral disc). Fortschr Rontgenstr 1928;38:265–79.
[39] Wagner AL, Murtagh FR, Arrington JA, Stallworth D. Relationship of Schmorl's nodes to vertebral body endplate fractures and acute endplate disc extrusions. AJNR Am J Neuroradiol 2000;21:276–81.
[40] Ministry of Health, Labour and Welfare. The outline of the results of National Livelihood Survey 2007. Available at: http://www.mhlw.go.jp/toukei/list/20-19-1.html. Accessed December 24, 2014.
[41] Jensen TS, Karppinen J, Sorensen JS, Niinimaki J, Leboeuf-Yde C. Vertebral endplate signal changes (Modic change): a systematic literature review of prevalence and association with non-specific low back pain. Eur Spine J 2008;17:1407–22.

The Spine Journal 14 (2014) 2811–2817

Clinical Study

The prevalence of cervical myelopathy among subjects with narrow cervical spinal canal in a population-based magnetic resonance imaging study: the Wakayama Spine Study

Keiji Nagata, MD, PhD[a], Noriko Yoshimura, MD, PhD[b], Hiroshi Hashizume, MD, PhD[a,*], Shigeyuki Muraki, MD, PhD[c], Yuyu Ishimoto, MD, PhD[a], Hiroshi Yamada, MD, PhD[a], Noboru Takiguchi, MD, PhD[a], Yukihiro Nakagawa, MD, PhD[a], Akihito Minamide, MD, PhD[a], Hiroyuki Oka, MD[b], Hiroshi Kawaguchi, MD, PhD[d], Kozo Nakamura, MD, PhD[e], Toru Akune, MD, PhD[c], Munehito Yoshida, MD, PhD[a]

[a]*Department of Orthopaedic Surgery, Wakayama Medical University, 811-1, Kimiidera, Wakayama City, 641-8510, Japan*

[b]*Department of Joint Disease Research, 22nd Century Medical and Research Center, Graduate School of Medicine, The University of Tokyo, 7-3-1, Hongo, Bunkyo-ku, Tokyo, 113-8654, Japan*

[c]*Department of Clinical Motor System Medicine, 22nd Century Medical & Research Center, Faculty of Medicine, The University of Tokyo, 7-3-1, Hongo, Bunkyo-ku, Tokyo, 113-8654, Japan*

[d]*Japan Community Health Care Organization Tokyo Shinjuku Medical Center, 6-1-1 Shinjuku, Shinjuku-ku, Tokyo 160-8402, Japan*

[e]*Rehabilitation Services Bureau, National Rehabilitation Center for Persons with Disabilities, 1, Namiki 4-chome, Tokorozawa City, Saitama Prefecture 359-8555, Japan*

Received 14 August 2013; revised 26 December 2013; accepted 18 March 2014

Abstract

BACKGROUND CONTEXT: A narrow cervical spinal canal (CSC) is a well-known risk factor for cervical myelopathy (CM). However, no epidemiologic data of the CSC based on a population-based cohort are available.

PURPOSE: The purpose of the study was to investigate the age-related differences in CSC diameters on plain radiographs and to examine the associated magnetic resonance imaging (MRI) abnormalities including cervical cord compression and increased signal intensity (ISI) as well as the clinical CM with the narrow CSC.

STUDY DESIGN/SETTING: This was a cross-sectional study.

PARTICIPANT SAMPLE: Data were obtained from the baseline survey of the Wakayama Spine Study that was performed from 2008 to 2010 in a western part of Japan. Finally, a total of 959 subjects (319 men and 640 women; mean age, 66.4 years) were included.

OUTCOME MEASURES: The outcome measures included in the study were the CSC diameter at C5 level on plain radiographs, cervical cord compression and ISI on sagittal T2-weighted MRI, and physical signs related to CM (eg, the Hoffmann reflex, hyperreflexia of the patellar tendon, the Babinski reflex, sensory and motor function, and bowel/bladder symptoms).

FDA device/drug status: Not applicable.

Author disclosures: ***KNag:*** Grant: Grant No.255 for young investigator from Japan Orthopedics and Traumatology Foundation (B, Paid directly to institution). ***NY:*** Grant: Grant-in-Aid for Scientific Research B23390172 and B20390182 (E, Paid directly to institution), Collaborating Research with NSF 08033011-00262 from the Ministry of Education, Culture, Sports, Science and Technology (E, Paid directly to institution). ***HH:*** Grant: The consigned research fund of Wakayama Prefecture Nos. B-23004 and B-24001 (C, Paid directly to institution). ***SM:*** Grant: Grant-in-Aid for Scientific Research C20591774 (D, Paid directly to institution). ***YI:*** Nothing to disclose. ***HY:*** Grant: Grant-in-Aid for Scientific Research C22591639 and C25462305 (E: Paid directly to institution). ***NT:*** Nothing to disclose. ***YN:*** Nothing to disclose. ***AM:*** Nothing to disclose. ***HO:*** Grant: Grant-in-Aid for Scientific Research for young scientists A18689031 (D, Paid directly to institution). ***HK:*** Nothing to disclose. ***KNak:*** Nothing to disclose. ***TA:*** Grant: Grant-in-Aid for Scientific Research C20591737 and H23-Chojyu-002 from the Ministry of Health, Labour and Welfare in Japan (E, Paid directly to institution). ***MY:*** Nothing to disclose.

The disclosure key can be found on the Table of Contents and at www.TheSpineJournalOnline.com.

Conflicts of interest and source of funding: No funds were received in support of this work. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

* Corresponding author. Department of Orthopaedic Surgery, Wakayama Medical University, 811-1 Kimidera, Wakayama City, Wakayama 641-8510, Japan. Tel.: +81-73-441-0645; fax.: +81-73-448-3008.

E-mail address: hashizum@wakayama-med.ac.jp (H. Hashizume)

http://dx.doi.org/10.1016/j.spinee.2014.03.051

METHODS: The age-related differences of CSC diameters in men and women were investigated by descriptive statistics. The prevalence of MRI abnormalities and clinical CM was compared among the groups divided by the CSC diameter (less than 13, 13–15, and 15 mm or more). In addition, a logistic regression analysis was performed to determine the association of the CSC diameter with cervical cord compression/clinical CM after overall adjustment for age, sex, and body mass index.
RESULTS: The CSC diameter was narrower with increasing age in both men and women. The prevalence of cervical cord compression, ISI, and the clinical CM was significantly higher in the narrower CSC group. The prevalence of cervical cord compression, ISI, and CM among subjects with CSC diameter less than 13 mm was 38.0%, 5.4%, and 10.1%, respectively. In the logistic model, the CSC diameter was a significant predictive factor for the clinical CM ($p<.0001$).
CONCLUSIONS: This study firstly confirmed the age-related differences in CSC diameters and the significant association of the narrow CSC diameter with CM in a population-based cohort.

Keywords: Cervical spine; Spinal canal stenosis; Cervical myelopathy; Magnetic resonance imaging; Population-based cohort; Epidemiology

Introduction

In cervical spinal disorders such as cervical myelopathy (CM) and spinal cord injury, developmental cervical spinal canal (CSC) stenosis has been considered as an effective predictor of clinical outcome [1,2]. The spinal cord area should be evaluated after comparing with data obtained from asymptomatic subjects of each age group. Age-dependent data are required because the spinal cord may change with age, just as the cerebrum decreases in size with age in elderly subjects. The spinal canal should also be considered in asymptomatic subjects when treating cervical spinal disorders because patients with a tight spinal canal are more susceptible to spinal cord damage. However, the prevalence of spinal cord disorders and CM among patients with CSC of narrow diameter is not known. To date, few studies have focused on age-related differences in the cervical spinal cord and CSC [3,4]. Recent advances in magnetic resonance imaging (MRI) have made it possible to noninvasively obtain clear images of the cervical spinal cord, thereby making evaluation of traumatic spinal cord injury and cervical cord compression more applicable in routine practice. This study was undertaken to clarify age-related differences in the cervical spinal cord and CSC using magnetic resonance imaging (MRI) to establish the basis for morphometric evaluation of patients with cervical spinal cord disorders. More specifically, the purposes of this study were to investigate age-related changes of the CSC in a population-based cohort in Japan and to examine the associated MRI abnormalities including cervical cord compression and increased signal intensity (ISI) as well as the clinical CM with the narrow CSC diameters.

Participants and methods

Participants

The present study is a part of ‘‘The Wakayama Spine Study: a population-based cohort,’’ which was a large-scale population-based MRI study. Because a detailed profile of the Wakayama Spine Study has already been described elsewhere, only a brief summary is provided here [5,6]. The Wakayama Spine Study was conducted between 2008 and 2010 in a mountainous region in Hidakagawa, Wakayama, and a coastal region in Taiji, Wakayama. From inhabitants of the Hidakagawa and Taiji regions, 1,063 potential study subjects were recruited for MRI examinations. Among those 1,063 candidates, 52 declined the examination; therefore, 1,011 inhabitants were registered in the present study. Among those 1,011 participants, individuals with MRI-sensitive implanted devices (such as a pacemaker) and other disqualifiers were excluded. Ultimately, the cervical spine was scanned with MRI in 985 participants. Four participants who had undergone a previous cervical operation were excluded from the analysis, and another four participants whose MRI interpretation was difficult because of poor image quality were also excluded. After these exclusions, the present study had 977 participants. Radiographic evaluation of the cervical spine was also performed in 959 of the subjects. In total, both MRI and radiographic results were available for 959 participants (319 men and 640 women) with an age range of 21 to 97 years (mean, 67.3 years for men and 65.9 years for women). The participants completed an interviewer-administered questionnaire of 400 items that included lifestyle information; and anthropometric and physical performance measurements were taken. All study participants provided informed consent, and the study design was approved by the appropriate ethics review boards.

Anthropometric measurements included height (meter), weight (kilogram), and body mass index (BMI; weight [kilogram]/height^2 [m^2]). Medical information concerning neck pain, sensory disturbances, the Hoffmann reflex, the Babinski reflex, and the deep tendon reflex of the patellar tendon was gathered by an experienced orthopedic surgeon. The Hoffmann reflex was elicited with the hand in a neutral position by flicking the distal phalanx of the middle finger and observing flexion of the distal phalanx of the thumb [7,8].

The Babinski reflex was elicited by firmly sweeping from the lateral part of the sole to the base of the toes with a pointed end of a reflex hammer and observing the hallux extensor response [9,10]. Hyperreflexia of the patellar tendon, a positive Hoffmann reflex, and a positive Babinski reflex were defined as aggravation on both sides. A myelopathic sign was defined as the presence of hyperreflexia of the patellar tendon, Hoffmann reflex, or Babinski reflex.

Measurements of CSC diameter and canal-to-body ratio on radiographs

All subjects also underwent lateral radiography with their neck in the neutral position. They were told by an X-ray technician to look straight ahead in a relaxed position. The radiographic data were scanned and calibrated using the ruler, which was put on the film. The sagittal spinal canal diameter at the C5 level was measured as the shortest distance from the midpoint between the vertebral body's superior and inferior end plates to the spinolaminar line. The canal-to-body ratio (CBR) was obtained by dividing the diameter of the spinal canal by that of the vertebral body to assess the tightness of the spinal canal and also to eliminate the magnification effect of radiographs.

Magnetic resonance imaging

An MRI scan of the cervical spine was obtained for each participant using a 1.5-T Excelart imaging system (Toshiba, Tokyo, Japan). All scans were taken in the supine position, except for participants with a rounded back, who used a triangular pillow under their heads and knees. The imaging protocol included a sagittal T2-weighted fast spin-echo pulse sequence (repetition time: 4,000 ms; echo time: 120 ms; and field of view: 300 $\times$ 320 mm) and an axial T2-weighted fast spin-echo pulse sequence (repetition time: 4,000 ms; echo time: 120 ms; and field of view: 180 $\times$ 180 mm).

MRI measures

Midsagittal T2-weighted images were assessed by an experienced orthopedic surgeon (Keiji Nagata), who was blinded to participants' clinical status.

Evaluation of cervical cord compression

Cervical cord compression was defined as compression with an anterior and/or a posterior component of the spinal cord [6]. Cervical cord compression was evaluated at each intervertebral level from C2–C3 to C7–T1.

Evaluation of signal intensity of the spinal cord

Increased signal intensity was defined as a high-intensity area in contrast with the adjacent isointensity portion of the spinal cord [11]. The ISI was evaluated in the area from C2 to T1.

Measurement of spinal cord diameter

The spinal cord diameter was measured manually at the midpoint of the C5 vertebral body level using the imaging software OsiriX (http://www.osirix-viewer.com/).

Definition of clinical CM

Myelopathy is defined clinically by the presence of myelopathic signs (eg, the Hoffmann reflex, hyperreflexia of the patellar tendon, and the Babinski reflex), usually accompanied by bilateral sensory deficits or sensory level and bowel/bladder symptoms. Among participants with myelopathic signs, cervical cord compression was the essential condition for diagnosing CM.

Statistical analyses

A comparison of baseline characteristics between sexes was performed using the Student *t* test. Differences in the CSC diameter, vertebral body, spinal cord, and CBR among men and women were determined using the Student *t* test. One-way analysis of variance was used to evaluate the differences in CSC diameter, vertebral body, spinal cord, and CBR among different age groups. The chi-square test was used to assess the presence of ISI among different age groups.

For categorical data, the chi-square test was used to assess the presence of significant differences among different diameters of the CSC. For continuous outcomes, the analysis of variance test was used to assess differences among different diameters of the CSC. In addition, to determine the association of ISI, CSC diameter, and CBR with cervical cord compression and CM, logistic regression analysis was used after overall adjustment for age, sex, and BMI. All statistical tests were performed at a significance level of .05 (two-sided). Data analyses were performed using JMP, version 8 (SAS Institute, Inc, Cary, NC, USA).

Results

Characteristics of the participants

The baseline characteristics of the 977 participants, including data for anthropometric measurements and physical performance, are listed in Table 1. There was no

Table 1
Characteristics of men and women participating in the present study

Characteristic	Men	Women
N	319	640
Age, y	67.3±13.8	65.9±13.3
Height, cm	164.6±7.2**	151.6±7.2
Weight, kg	64.4±11.6**	53.0±9.4
Body mass index, kg/m^2	23.7±3.4*	23.1±3.7
Grip strength, kg	37.9±9.1**	23.9±5.9

Note: Significantly different from women by the Student *t* test (*p<.01; **p<.001).

Values are the mean±standard deviation.

Table 2
Radiographic and MRI measures stratified by gender and age strata

Age strata	Radiographic measures: Diameter of cervical spinal canal (mm)	Radiographic measures: Canal-to-body ratio	MRI measures: Increased signal intensity, N (%)	MRI measures: Diameter of spinal cord (mm)
Men				
Overall	14.8±1.3	0.82±0.12	15 (4.6)	6.9±0.9
<50 y	15.2±1.3	0.86±0.09	2 (5.2)	7.3±0.8
50–59 y	14.8±1.7	0.85±0.13	4 (6.9)	7.1±0.9
60–69 y	14.9±1.2	0.82±0.11	3 (4.5)	6.9±0.7
70–79 y	14.8±1.2	0.82±0.11	2 (2.3)	6.9±0.8
≥80 y	14.4±1.1	0.79±0.12	4 (5.5)	6.6±0.9
Women				
Overall	14.1±1.2	0.92±0.13	11 (1.7)	6.8±0.9
<50 y	14.5±1.3	0.99±0.14	1 (1.1)	6.9±0.9
50–59 y	14.4±1.3	0.96±0.12	1 (0.0)	7.0±0.7
60–69 y	14.1±1.1	0.91±0.12	0 (0)	6.8±0.8
70–79 y	13.9±1.1	0.89±0.12	6 (3.5)	6.8±0.9
≥80 y	13.8±1.0	0.86±0.12	3 (2.5)	6.7±0.9

Note: Otherwise indicated, values are mean±standard deviation for each age strata in men and women.

significant difference in age between sexes. Height, weight, and BMI were significantly higher in men than in women.

Age and sex differences of CSC diameter, CBR, ISI, and spinal cord diameter

Table 2 lists the age-related differences in diameters of the CSC, the CBR on radiograph, ISI, and spinal cord diameter on MRI in men and women among different age groups. The CSC diameter was significantly narrower with age in women (p<.0001). In men, the CSC diameter had a tendency to be narrower with age, but it was not significantly different in women. The mean diameter of the CSC was not significantly different between men and women. The diameter of the vertebral body was significantly higher in men and women with increasing age (p<.0001). The mean CBR in men and women was 0.82 and 0.92, respectively, and it was significantly higher in women than in men at the C5 vertebral level. The CBR was significantly lower with increasing age in both sexes (men, p=.0004; women: p<.0001).

The prevalence of ISI in all participants was 2.7% (4.6% in men and 1.7% in women) and was significantly higher in men than in women (p=.007). The prevalence of ISI was not significantly different with age between sexes. The diameter of the spinal cord was significantly lower with increasing age in both sexes (men, p=.0012; women, p=.0068). The mean diameter of the spinal cord was not significantly different between men and women.

Prevalence of MRI measures and CM among different diameters of the CSC

Anthropometric measures such as CSC diameter were found to be significantly different according to age (Table 3). Regarding MRI measures, significant differences between different CSC diameters were found with respect to cervical cord compression (p<.0001), ISI (p<.0001), and spinal cord diameter (p<.0001), except for ISI in women. The prevalence of cervical cord compression, ISI, and CM in subjects with a CSC diameter less than 13 mm was 61.9%, 23.8%, and 4.8% in men, respectively. Meanwhile, the prevalence of cervical cord compression, ISI, and CM among female subjects with a CSC diameter less than 13 mm was 33.3%, 1.9%, and 11.1%, respectively. Multiple logistic regression analysis was performed to estimate the predictive factors for CM in MRI and radiographic measurements after adjustment for age, sex, and BMI (Table 4). As an overall result, ISI, CSC diameter, and CBR were significant predictive factors for CM (p<.01). There was a positive association between cervical cord compression and spinal cord diameter, whereas spinal cord diameter itself was not a significant predictive factor for CM.

Discussion

The present study is the first population-based study to clarify the normal value of the diameter of the CSC and its association with cervical cord compression, ISI, and CM in Japanese men and women. We clarified that the CSC diameter was narrower with age in both men and women in the population-based cohort. The prevalence of the clinical CM was significantly higher in the narrower CSC group. Furthermore, in the logistic model, the CSC diameter was a significant predictive factor for clinical CM.

In this study, the CSC and vertebral body diameters were measured using plain radiographs because the posterior longitudinal ligament could not be distinguished from the vertebral body on MRI. There have been several reports on the diameter of the CSC. Porter et al. [12] reported that canal size did not appear to change significantly with biomechanical stress and aging. Meanwhile, Goto et al. [3] and Kato et al. [4] reported that the younger generation (younger than 40 years of age) had a statistically wider CSC. Our result was consistent with the latter reports. Why do younger persons have a wider CSC than elderly persons? There are two possible reasons for the differences in CSC diameter between generations. First, the CSC diameter becomes narrower with aging. A CSC with a small diameter is primarily a developmental and not a degenerative phenomenon. However, Hukuda and Kojima [13] reported that the diameter of the vertebral body was wider in older people compared with younger people. Those morphologic changes of the vertebral component may affect the diameter of the CSC. Second, the changes in Japanese eating habits and physique in the past few decades may have contributed to the changes in the diameter of the CSC. The variation of CSC diameter with different generation may be a limited phenomenon in Japan. However, we believe the results prompt future investigations into the various factors affecting the CSC dimensions, apart from aging.

Table 3
Prevalence of MRI measures and cervical myelopathy among different diameter of cervical spinal canal

Factors	Diameter of cervical spinal canal (mm) <13	13–15	≥15	p value
Men				
N	21	162	136	
Age, y	69.5±12.0	69.1±12.8	64.9±14.9	.027
Height, cm	163.7±5.6	163.6±6.8	165.8±7.7	.025
Weight, kg	67.6±10.5	61.7±10.6	67.0±12.3	.0002
Body mass index, kg/m^2	25.2±3.3	23.0±3.2	24.2±3.4	.0006
MRI measures				
Cervical cord compression, N (%)	13 (61.9)	58 (35.8)	22 (16.2)	<.0001
Increased signal intensity, N (%)	5 (23.8)	9 (5.6)	1 (0.7)	<.0001
Diameter of spinal cord (mm)	6.2±0.5	6.8±0.8	7.2±0.8	<.0001
Cervical myelopathy, N (%)	1 (4.8)	2 (1.2)	0 (0)	.09
Women				
N	108	383	149	
Age, y	68.7±13.3	67.2±12.8	60.4±13.4	<.0001
Height, cm	149.1±7.2	151.4±7.1	153.9±6.7	<.0001
Weight, kg	49.8±8.1	53.2±9.6	54.8±9.4	.0001
Body mass index, kg/m^2	22.4±3.2	23.2±3.7	23.2±3.8	.12
MRI measures				
Cervical cord compression, N (%)	36 (33.3)	92 (24.0)	11 (7.4)	<.0001
Increased signal intensity, N (%)	2 (1.9)	8 (2.1)	0 (0)	.21
Diameter of spinal cord (mm)	6.5±0.9	6.9±0.8	7.0±0.8	<.0001
Cervical myelopathy, N (%)	12 (11.1)	12 (3.1)	0 (0)	<.0001

MRI, magnetic resonance imaging.

Note: For categorical data, the chi-square test was used to assess the presence of significant differences among different diameters of the cervical spinal canal.

For continuous outcomes, comparison was made by the analysis of variance test differences among different diameters of the cervical spinal canal.

Regarding MRI measurements, the prevalence of cervical cord compression and ISI among persons with a CSC diameter less than 13 mm, which was considered to be developmental canal stenosis [14], was 61.9% and 23.8% in men and 33.3% and 1.9% in women, respectively. Above all, a CSC diameter less than 13 mm was observed in more than 10% of the participants. Of those with a CSC diameter less than 13 mm, cervical cord compression (ie, the preliminary step in the development of CM) was also observed in 61.9% of men and 33.3% of women. From these results, the number of people who have a risk for CM was considered quite high in the general population. Countee and Vijayanathan [15] reported that congenital stenosis in men with a cervical canal diameter of 14 mm or less was associated with quadriplegia after trauma. In the present study, we noted that the narrower the diameter of the CSC, the higher the prevalence of ISI. Of note, the distribution of prevalence between men and women was different. Increased signal intensity was seen in approximately 10% of men younger than 60 years, whereas it was seen in only 1% of women younger than 60 years, and was relatively higher in older people. In the present study, the prevalence of the clinical CM was significantly higher in the narrower CSC group. The result may show that patients with a narrowed spinal canal are more likely to develop CM. Further longitudinal studies are needed to clarify the causal

Table 4
The odds ratio and 95% confidence interval of increased signal intensity, diameter of spinal cord, diameter of cervical spinal canal, and canal-to-body ratio for cervical myelopathy

Variables	Cervical cord compression OR* (95% CI)	p value	Cervical myelopathy OR (95% CI)	p value
Age, y (+10 y)	23.6 (9.62–60.0)	<.0001	11.0 (1.15–133.9)	.047
Women (vs. men)	1.41 (1.03–1.92)	.032	4.33 (1.50–18.4)	.018
Body mass index, kg/m^2 (+1 SD)	2.12 (0.87–5.16)	.095	1.04 (0.94–1.15)	.41
Increased signal intensity positive	18.8 (6.87–66.4)	<.0001	6.32 (1.36–21.8)	.007
Diameter of spinal cord, mm (−1 mm)	1.40 (1.17–1.68)	.0002	1.46 (0.93–2.31)	.11
Diameter of cervical spinal canal, mm (−1 mm)	1.67 (1.45–1.93)	<.0001	2.73 (1.83–4.23)	<.001
Canal-to-body ratio (−10%)	1.85 (1.60–2.16)	<.0001	2.12 (1.47–3.16)	.0001

OR, odds ratio; CI, confidence interval; SD, standard deviation.

* OR was calculated by multiple logistic regression analysis after adjustment for age, gender, and body mass index.

relationship between narrowed spinal canal and CM. In addition, we clarified the positive association between cervical cord compression and spinal cord diameter, whereas the diameter of the spinal cord itself was not a significant predictive factor for CM. This may indicate that the spinal cord can become atrophied in individuals with cervical cord compression or in those who have a congenitally narrow spinal cord.

The present study also clarified the difference in age- and sex-related changes in the CSC diameter and CBR. The CSC has been the focus as a risk factor for CM [14,16]. However, in recent years, the CBR rather than CSC diameter has been reported to be a useful predictor for CM because of a magnification error resulting from the focus-to-film distance and the object-film distance on MRI [17]. However, Blackley et al. [18] showed that there is currently a poor correlation between the CBR and the true sagittal diameter of the spinal canal on computed tomography scans because of the wide normal variations in the diameter of the vertebral body. Therefore, the characteristics of the variations between the CSC diameter and the CBR should be considered. Of note, the present study found the CSC diameter to be higher in men than in women. However, the CBR was higher in women than in men, which is the reason for the increased diameter of the vertebral body in men. Therefore, the differences between the sexes should be taken into account when considering the CBR as a risk factor for CM.

Study limitations

The present study had several limitations. First, although more than 1,000 participants were included in the present study, these participants may not represent the general population because they were recruited from only two areas of Japan. However, anthropometric measurements were compared between the participants of the present study and the general Japanese population [19], and no significant differences in BMI were found between the participants in the present study and the Japanese population at large in both sexes (BMI [standard deviation] in men: 23.71 kg/m^2 [3.41 kg/m^2] and 23.95 kg/m^2 [2.64 kg/m^2], p=.33, respectively; BMI [standard deviation] in women: 23.06 kg/m^2 [3.42 kg/m^2] and 23.50 kg/m^2 [3.69 kg/m^2], p=.07, respectively). Second, the distribution of the CSC diameter applies to only a small portion of the Japanese population and cannot be extrapolated to other populations.

Conclusions

This study confirmed the significant association of the narrow CSC diameter with CM in a population-based cohort. The results prompt future studies to look into the various factors affecting the dimensions of the CSC, apart from aging.

Acknowledgments

The authors thank Dr. Takako Nojiri and Mr. Kazuhiro Hatanaka of the Gobo Public Health Centre; Dr. Naoki Hirabayashi of the Kawakami Clinic, Hidakagawa Town; Mrs. Tomoko Takijiri, Mrs. Kumiko Shinou, Mrs. Rie Takiguchi, Mrs. Kyoko Maeda, Ms. Ikuyo Ueyama, Mrs. Michiko Mori, Mrs. Hisayo Sugimoto, and other members of the public office in Hidakagawa Town; Dr. Shinji Matsuda of the Shingu Public Health Centre; and Mrs. Tamako Tsutsumi, Mrs. Kanami Maeda, Mr. Shoichi Shimoichi, Mrs. Megumi Takino, Mrs. Shuko Okada, Mrs. Kazuyo Setoh, Mrs. Chise Ryouno, Mrs. Miki Shimosaki, Mrs. Chika Yamaguchi, Mrs. Yuki Shimoji, and other members of the public office in Taiji Town for their assistance in locating and scheduling participants for examinations. The authors also thank Ms. Kyoko Yoshimura, Mrs. Toki Sakurai, and Mrs. Saeko Sahara for their assistance with data reduction and administration.

References

[1] Murone I. The importance of the sagittal diameters of the cervical spinal canal in relation to spondylosis and myelopathy. J Bone Joint Surg Br 1974;56:30–6.
[2] Eismont FJ, Clifford S, Goldberg M, et al. Cervical sagittal spinal canal size in spine injury. Spine 1984;9:663–6.
[3] Goto S, Umehara J, Aizawa T, et al. Comparison of cervical spinal canal diameter between younger and elder generations of Japanese. J Jap Orthop Ass 2010;15:97–103.
[4] Kato F, Yukawa Y, Suda K, et al. Normal morphology, age-related changes and abnormal findings of the cervical spine. Part II: magnetic resonance imaging of over 1,200 asymptomatic subjects. Eur Spine J 2012;21:1499–507.
[5] Ishimoto Y, Yoshimura N, Muraki S, et al. Prevalence of symptomatic lumbar spinal stenosis and its association with physical performance in a population-based cohort in Japan: the Wakayama Spine Study. Osteoarthritis Cartilage 2012;20:1103–8.
[6] Nagata K, Yoshimura N, Muraki S, et al. Prevalence of cervical cord compression and its association with physical performance in a population-based cohort in Japan: the Wakayama Spine Study. Spine 2012;37:1892–8.
[7] Houten JK, Noce LA. Clinical correlations of cervical myelopathy and the Hoffmann sign. J Neurosurg Spine 2008;9:237–42.
[8] Sung RD, Wang JC. Correlation between a positive Hoffmann's reflex and cervical pathology in asymptomatic individuals. Spine 2001;26:67–70.
[9] Rhee JM, Heflin JA, Hamasaki T, et al. Prevalence of physical signs in cervical myelopathy: a prospective, controlled study. Spine 2009;34:890–5.
[10] Harrop JS, Hanna A, Silva MT, et al. Neurological manifestations of cervical spondylosis: an overview of signs, symptoms, and pathophysiology. Neurosurgery 2007;60(1 Supp1 1):S14–20.
[11] Matsumoto M, Toyama Y, Ishikawa M, et al. Increased signal intensity of the spinal cord on magnetic resonance images in cervical compressive myelopathy. Does it predict the outcome of conservative treatment? Spine 2000;25:677–82.
[12] Porter RW, Hibbert C, Wellman P. Backache and the lumbar spinal canal. Spine 1980;5:99–105.
[13] Hukuda S, Kojima Y. Sex discrepancy in the canal/body ratio of the cervical spine implicating the prevalence of cervical myelopathy in men. Spine 2002;27:250–3.

[14] Arnold JG Jr. The clinical manifestations of spondylochondrosis (spondylosis) of the cervical spine. Ann Surg 1955;141:872–89.

[15] Countee RW, Vijayanathan T. Congenital stenosis of the cervical spine: diagnosis and management. J Natl Med Assoc 1979;71: 257–64.

[16] Wolf BS, Khilnani M, Malis L. The sagittal diameter of the bony cervical spinal canal and its significance in cervical spondylosis. J Mt Sinai Hosp NY 1956;23:283–92.

[17] Pavlov H, Torg JS, Robie B, et al. Cervical spinal stenosis: determination with vertebral body ratio method. Radiology 1987;164:771–5.

[18] Blackley HR, Plank LD, Robertson PA. Determining the sagittal dimensions of the canal of the cervical spine. The reliability of ratios of anatomical measurements. J Bone Joint Surg Br 1999;81:110–2.

[19] Ministry of Health, Labour and Welfare. The report of National Health and Nutrition Survey 2005. Available at: www.mhlw.go.jp/bunya/kenkou/eiyou/dl/h20-houkoku-04.pdf. Accessed May 30, 2013.

J Bone Miner Metab (2014) 32:524–532
DOI 10.1007/s00774-013-0522-1

ORIGINAL ARTICLE

Prevalence of knee pain, lumbar pain and its coexistence in Japanese men and women: The Longitudinal Cohorts of Motor System Organ (LOCOMO) study

Noriko Yoshimura · Toru Akune · Saeko Fujiwara · Yoko Shimizu · Hideyo Yoshida · Go Omori · Akihiro Sudo · Yuji Nishiwaki · Munehito Yoshida · Hiroshi Shimokata · Takao Suzuki · Shigeyuki Muraki · Hiroyuki Oka · Kozo Nakamura

Received: 9 July 2013 / Accepted: 9 September 2013 / Published online: 9 November 2013

Abstract The Longitudinal Cohorts of Motor System Organ (LOCOMO) study was initiated in 2008 through a grant from the Ministry of Health, Labour, and Welfare of Japan to integrate information from several cohorts established for the prevention of musculoskeletal diseases. We integrated the information of 12,019 participants (3,959 men and 8,060 women) in the cohorts comprising nine communities located in Tokyo (two regions: Tokyo-1 and Tokyo-2), Wakayama [two regions: Wakayama-1 (mountainous region) and Wakayama-2 (seaside region)], Hiroshima, Niigata, Mie, Akita, and Gunma prefectures. The baseline examination of the LOCOMO study consisted of an interviewer-administered questionnaire, anthropometric measurements, medical information recording, X-ray radiography, and bone mineral density measurement. The prevalence of knee pain was 32.7 % (men 27.9 %; women 35.1 %) and that of lumbar pain was 37.7 % (men 34.2 %; women 39.4 %). Among the 9,046 individuals who were surveyed on both knee pain and lumbar pain at the baseline examination in each cohort, we noted that the prevalence of both knee pain and lumbar pain was 12.2 % (men 10.9 %; women 12.8 %). Logistic regression analysis showed that higher age, female sex, higher body mass index (BMI), living in a rural area, and the presence of lumbar pain significantly influenced the presence of knee pain. Similarly, higher age, female sex, higher BMI, living in a rural area, and the presence of knee pain significantly influenced the presence of lumbar pain. Thus, by using the data of the

N. Yoshimura (✉) · H. Oka
Department of Joint Disease Research, 22nd Century Medical and Research Center, Graduate School of Medicine, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8655, Japan
e-mail: yoshimuran-ort@h.u-tokyo.ac.jp

T. Akune · S. Muraki
Department of Clinical Motor System Medicine, 22nd Century Medical and Research Center, Graduate School of Medicine, University of Tokyo, Tokyo, Japan

S. Fujiwara
Hiroshima Atomic Bomb Casualty Council, Hiroshima, Japan

Y. Shimizu · H. Yoshida
Tokyo Metropolitan Institute of Gerontology, Tokyo, Japan

G. Omori
Center for Transdisciplinary Research, Institute for Research Promotion, Niigata University, Niigata, Japan

A. Sudo
Department of Orthopaedic Surgery, Mie University Graduate School of Medicine, Mie, Japan

Y. Nishiwaki
Department of Environmental and Occupational Health, School of Medicine, Toho University, Tokyo, Japan

M. Yoshida
Department of Orthopedic Surgery, School of Medicine, Wakayama Medical University, Wakayama, Japan

H. Shimokata
Graduate School of Nutritional Sciences, Nagoya University of Arts and Sciences, Aichi, Japan

T. Suzuki
National Center for Geriatrics and Gerontology, Aichi, Japan

K. Nakamura
National Rehabilitation Center for Persons with Disabilities, Saitama, Japan

LOCOMO study, we clarified the prevalence of knee pain and lumbar pain, their coexistence, and their associated factors.

Keywords Nation-wide population-based cohort study · Epidemiology · Prevalence · Knee pain · Lumbar pain

Introduction

Musculoskeletal diseases, including osteoarthritis (OA) and osteoporosis (OP), are major public health problems among the elderly; these diseases can affect activities of daily living (ADL) and quality of life (QOL), and can lead to increased morbidity and mortality. According to the recent National Livelihood Survey by the Ministry of Health, Labour, and Welfare in Japan, OA is ranked fourth among diseases that cause disabilities and subsequently require support for ADL, whereas falls and osteoporotic fractures are ranked fifth [1]. Studies have reported increased mortality after osteoporotic fractures at the hip and other sites [2]. An estimated 47,000,000 individuals (21,000,000 men and 26,000,000 women) aged ≥40 years will eventually be affected by either OA or OP [3].

Considering that the population of Japan is aging rapidly, a comprehensive and evidence-based prevention strategy for musculoskeletal diseases is urgently needed. However, only a few prospective, longitudinal studies designed to develop such a strategy have been conducted. Therefore, little information is available regarding the incidence of disability and the prevalence and incidence of musculoskeletal disorders, including knee pain, and lumbar pain, and their associated factors in Japan. The absence of such epidemiological data hampers the rational design of clinical and public health approaches for the diagnosis, evaluation, and prevention of musculoskeletal diseases.

Several cohorts have focused on the prevention of OP, knee OA (KOA), lumbar spondylosis (LS) or disability caused by musculoskeletal diseases. However, since the prevalence of the musculoskeletal diseases has been reported to be high [3], the extent of the population at risk after excluding those who had the target disease at the baseline seems to be small. To identify epidemiological indices, especially the incidence of musculoskeletal diseases and/or disability, a large number of subjects is required. In addition, to determine the regional differences in epidemiological indices, we need a survey of cohorts across Japan.

The Longitudinal Cohorts of Motor System Organ (LOCOMO) study was initiated in 2008 by the members of the committee for ‘the prevention of knee and back pain and bone fractures in a large cohort of regionally representative residents from across Japan,’ through a grant from the Ministry of Health, Labour, and Welfare of Japan (Director, Noriko Yoshimura). This study aimed to integrate the information of several cohorts established for the prevention of musculoskeletal diseases from 2000 onwards, and to initiate a follow-up examination using the unified questionnaire from 2006 onwards in Japan.

In the present paper, by using the integrated information at the baseline of the LOCOMO study, we tried to confirm the prevalence of clinical symptoms of musculoskeletal diseases, such as knee pain and lumbar pain and their characteristics.

Materials and methods

Participants

Participants in the cohorts were residents of nine communities located in Tokyo (two regions: Tokyo-1, principle investigators (PIs): Shigeyuki Muraki, Toru Akune, Noriko Yoshimura, Kozo Nakamura; Tokyo-2, PIs: Yoko Shimizu, Hideyo Yoshida, Takao Suzuki), Wakayama [two regions: Wakayama-1 (mountainous region) and Wakayama-2 (seaside region); PIs: Noriko Yoshimura, Munehito Yoshida], Hiroshima (PI: Saeko Fujiwara), Niigata (PI: Go Omori), Mie (PI: Akihiro Sudo), Akita (PI: Hideyo Yoshida), and Gunma (PI: Yuji Nishiwaki) prefectures [4]. Figure 1 shows the location of each cohort in Japan, and Fig. 2 provides the timeline of the LOCOMO study. Residents of the nine regions were recruited from resident registration lists in the relevant region. Data for the 12,019 participants were collected and registered as an integrated cohort. Numbers of participants in the LOCOMO study classified by regions of each cohort are shown in Table 1. The smallest cohort consisted of 826 individuals in Wakayama-2, and the largest consisted of 2,613 individuals in Hiroshima.

All participants provided written informed consent, and the study was conducted with the approval of the ethics committees of the University of Tokyo (nos. 1264 and 1326), the Tokyo Metropolitan Institute of Gerontology (no. 5), Wakayama (no. 373), The Radiation Effects Research Foundation (RP03-89), Niigata University (no. 446), Mie University (no. 837 and no. 139), Keio University (no. 16–20), and National Center for Geriatrics and Gerontology (no. 249). Safety of the participants was ensured during the examination and during all other study procedures.

Data collection

The baseline examination of the LOCOMO study consisted of the following: an interviewer-administered questionnaire,

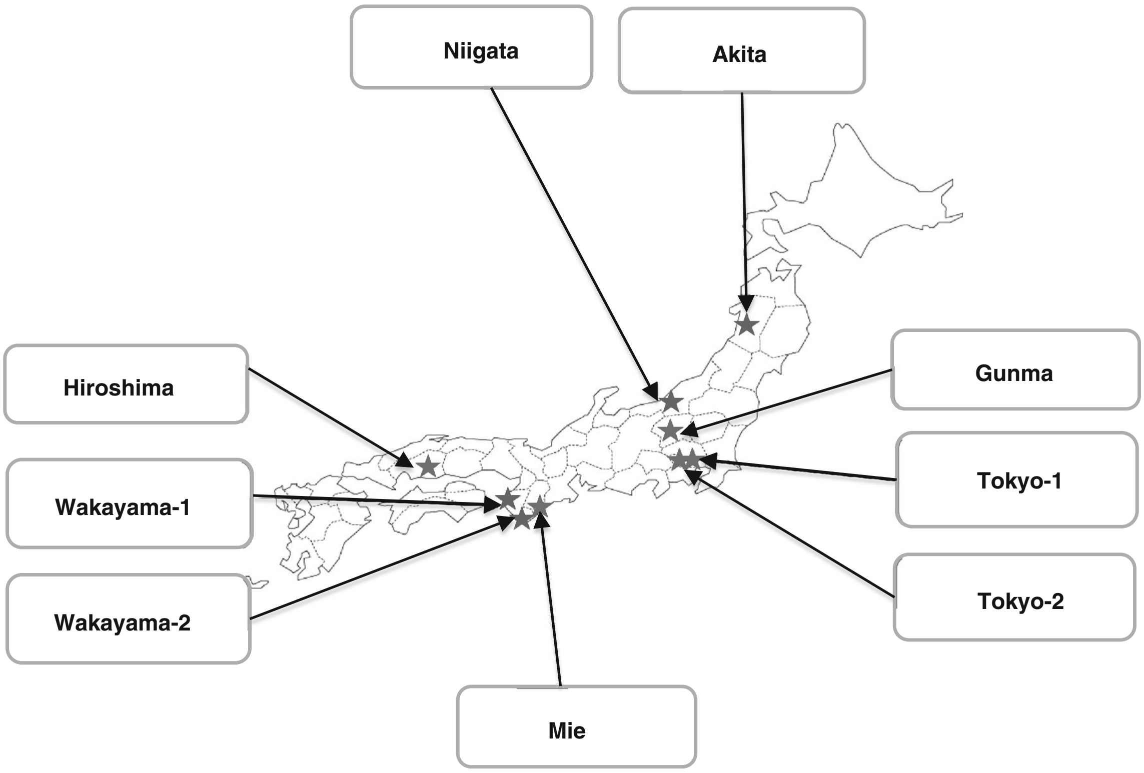


Fig. 1 Locations of the nine different regions from which the study cohorts were derived

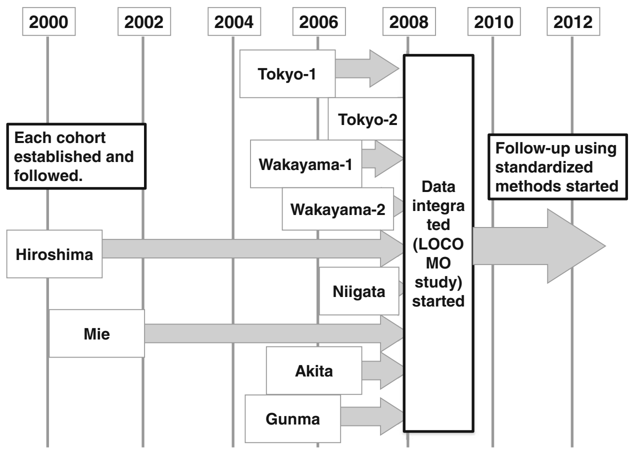


Fig. 2 Timeline of the LOCOMO study

Table 1 Numbers of participants in the LOCOMO study classified by regions of each cohort

Regions of each cohort	Start year	Total	Men	Women
Tokyo-1	2005	1,350	465	885
Tokyo-2	2008	1,453	59	1,394
Wakayama-1 (mountainous)	2005	864	319	545
Wakayama-2 (seaside)	2006	826	277	549
Hiroshima	2000	2,613	794	1,819
Niigata	2007	1,474	628	846
Mie	2001	1,175	423	752
Akita	2006	852	366	486
Gunma	2005	1,412	628	784
Total		12,019	3,959	8,060

anthropometric measurements, medical information recording, radiography, and bone mineral density (BMD) measurement.

Interviewer-administered questionnaire

A questionnaire was prepared by modifying the questionnaire used in the Osteoporotic Fractures in Men Study (MrOS) [5], and some new items were added to the modified questionnaire. Knee symptoms were evaluated using the Western Ontario and McMaster University Osteoarthritis Index (WOMAC) [6]. Health-related QOL was evaluated using the European QOL-5 dimensions instrument (EuroQOL EQ5D) [7] and the Medical Outcomes Study 8-item Short Form (SF-8) [8]. The study staff recorded all the medications administered and their doses.

Anthropometric measurements

Anthropometric factors were measured by well-trained medical nurses. Body mass index [BMI; weight in kilograms/(height in meters)^2] was calculated on the basis of the current height and weight. Hand grip strength was measured using a Toei Light handgrip dynamometer (Toei Light Co., Ltd., Saitama, Japan). Both hands were tested, and the higher value was used to characterise the maximum muscle strength of the subject. Walking speed was determined by recording the time taken by a subject to walk a determined distance, such as 5 or 6 m, at his/her usual speed. The ability to rise from a chair without using the arms (chair stand) and the ability to perform 5 chair stands was evaluated. The time required to complete the tasks was recorded.

Medical information

Medical information was obtained by experienced medical doctors in each cohort. All participants were questioned about pain in both knees by asking the following questions: 'Have you experienced right knee pain on most days (and continuously on at least one day) in the past month, in addition to the current pain?' and 'Have you experienced left knee pain on most days (and continuously on at least one day) in the past month, in addition to the current pain?' Subjects who answered 'yes' were considered to have knee pain. Lumbar pain was determined by asking the following question: 'Have you experienced lumbar pain on most days (and continuously on at least one day) in the past month, in addition to the current pain?' Subjects who answered 'yes' were considered to have lumbar pain.

In some cohorts (Tokyo-1, Wakayama-1, and Wakayama-2), the participants completed the modified Mini-Mental Status Examination-Japanese version [9] for evaluating cognitive function. Physicians explained any unclear sections of this questionnaire to the participants and assessed the cognitive status on the basis of the completed questionnaire.

Radiography and radiographic assessment

In several cohorts (Tokyo-1, Wakayama-1, Wakayama-2, Hiroshima, Niigata, and Mie), the radiographic examination of knees and/or spine was performed to evaluate the OA or fractures. Plain radiographs were obtained for both knees in the antero-posterior view with weight-bearing and foot map positioning and for the spine in the antero-posterior and lateral views.

The severity of OA was radiographically determined according to the Kellgren-Lawrence (KL) grading system as follows [10]: KL0, normal joint; KL1, slight osteophytes; KL2, definite osteophytes; KL3, narrowing of joint cartilage, and large osteophytes; and KL4, bone sclerosis, narrowing of joint cartilage, and large osteophytes. In the LOCOMO study, joints exhibiting disc-space narrowing alone and no large osteophytes were graded as KL3. In each cohort, radiographs were examined by a single, experienced orthopaedic surgeon who was masked to the clinical status of the participants. If at least one knee joint was graded as KL2 or higher, the participant was diagnosed with radiographic KOA. Similarly, if at least one intervertebral joint of the lumbar spine was graded as KL2 or higher, the participant was diagnosed with radiographic LS.

BMD measurement

In the Wakayama-1, Wakayama-2, and Hiroshima cohorts, BMD of the lumbar spine and proximal femur was measured using dual energy X-ray absorptiometry (DXA) (Hologic Discovery; Hologic, Waltham, MA, USA) during the baseline examination.

OP was defined on the basis of the World Health Organization (WHO) criteria. Specifically, OP was diagnosed when the BMD T scores were lower than the mean lumbar peak bone mass—2.5 SDs [11]. In Japan, the mean BMD of the L2–L4 vertebrae among both young male and female adults has been measured using Hologic DXA [12]. In the present study, lumbar spine BMD < 0.714 g/cm^2 (for both men and women) and femoral neck BMD < 0.546 g/cm^2 (men) or <0.515 g/cm^2 (women) were considered to indicate OP.

Statistical analysis

All statistical analyses were performed using STATA statistical software (STATA Corp., College Station, TX, USA). Differences in proportions were compared using the Chi square test. Differences in continuous variables were tested for significance using analysis of variance for comparisons among multiple groups or Scheffe's least significant difference test for pairs of groups. To test the association between the interaction between the knee pain and lumbar pain, a logistic regression model was used. First, the presence of knee pain was used as an objective variable (0: absence, 1: presence) and age (+1 year), gender (men vs. women), BMI (+1 kg/m^2), regional differences (0: rural areas including Wakayama-1, Wakayama-2, Niigata, Mie, Akita, and Gunma vs. 1: urban areas including Tokyo-1, Tokyo-2, and Hiroshima), and lumbar pain (0: no, 1: yes) were used as explanatory variables. Then, lumbar pain was used as an objective variable, and knee pain was used as an explanatory variable in the identical model. All p values and 95 % confidence intervals (CI) of two-sided analysis are presented.

Results

Table 2 shows the number of participants classified by age and gender. Most participants were aged $\geq$60 years, and

Table 2 Numbers of participants in the LOCOMO study classified by age and gender

Age strata (years)	Total (%)	Men (%)	Women (%)
≤39	125 (1.0)	49 (1.2)	76 (0.9)
40–49	483 (4.0)	183 (4.6)	300 (3.7)
50–59	963 (8.0)	320 (8.1)	643 (8.0)
60–69	3,170 (26.3)	1,161 (29.3)	2,009 (24.9)
70–79	5,041 (41.9)	1,573 (39.7)	3,468 (43.0)
80–89	2,111 (17.6)	627 (15.8)	1,484 (18.4)
≥90	126 (1.1)	46 (1.2)	80 (1.0)
Total	12,019 (100.0)	3,959 (100.0)	8,060 (100.0)

99.0 % of the participants were aged ≥40 years. Two-thirds of the participants were women, and their mean age was 1 year greater than that of the male participants.

Selected characteristics of the study populations, including age, height, weight, BMI, and proportions of participants who smoked and consumed alcohol are shown in Table 3. The participants were considered as smokers and alcohol consumers if they answered ‘yes’ to the question ‘Are you currently smoking/drinking?’ in the self-administered questionnaire. The mean values of age and BMI were significantly higher in women than in men ($p < 0.01$). The proportions of both current smokers and alcohol consumers were significantly higher among men than among women ($p < 0.001$).

Table 3 Baseline characteristics of participants in the LOCOMO study classified by age and gender

Variables	Men	Women	*p* Value (men vs. women)
Age (years)	70.0 (10.6)	71.0 (10.3)	<0.001
Height (cm)	161.1 (6.8)	148.5 (6.4)	<0.001
Weight (kg)	59.3 (9.5)	50.8 (8.6)	<0.001
BMI (kg/m^2)	22.8 (3.0)	23.0 (3.5)	0.007
Smoking (%)	34.0	4.8	<0.001
Drinking (%)	52.4	21.1	<0.001

Values are represented as mean (standard deviation)

BMI body mass index

By analysing the data at the baseline examination, we determined the prevalence of knee pain and lumbar pain. Figure 3 shows the age-sex distribution of the prevalence of knee pain and lumbar pain. Overall, the prevalence of knee pain was 32.7 % (27.9 % in men and 35.1 % in women) and that of lumbar pain was 37.7 % (34.2 % in men and 39.4 % in women). The prevalence of pain in both the knee and lumbar region were significantly higher in women than in men ($p < 0.001$). On the basis of the total age and sex distributions derived from the Japanese census in 2010 [13], our results estimate that 18,000,000 people (7,100,000 men and 10,900,000 women) aged ≥40 years would be affected by knee pain and that 27,700,000 people (12,100,000 men and 15,600,000 women) aged ≥40 years would be affected by lumbar pain.

Further, among 9,046 individuals who were surveyed on both knee pain and lumbar pain at the baseline examination in each cohort, the prevalence of both knee pain and lumbar pain was 12.2 % (10.9 % in men and 12.8 % in women). The prevalence of the coexistence of knee and lumbar pain in the participants aged <40, 40–49, 50–59, 60–69, 70–79, and ≥80 years was 4.0, 4.8, 7.4, 13.0, 13.3, and 11.7 %, respectively, (6.1, 5.3, 6.0, 10.0, 11.5, and 13.2 %, respectively, in men and 2.6, 4.6, 8.1, 14.8, 14.2, and 11.0 %, respectively, in women). The prevalence of both knee pain and lumbar pain increased with age in men, whereas that in women reached a plateau at 60–69 and 70–79 years and then declined. On the basis of the total age and sex distributions derived from the Japanese census in 2010 [13], our results estimate that 6,800,000 people

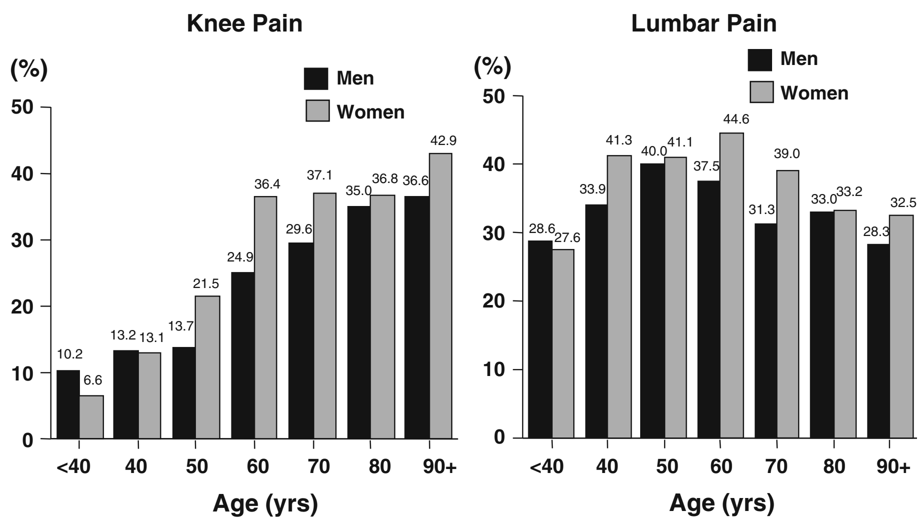


Fig. 3 Prevalence of knee pain and lumbar pain according to age and gender

Table 4 Odds ratios (OR) of potentially associated factors for the presence of knee pain/lumbar pain vs. absence of pain

Explanatory variables	Reference	OR	95% confident interval	p
Knee pain (presence vs. absence)				
Age (years)	+1 year	1.045	1.039–1.051	<0.001***
Gender	0: men, 1: women	1.602	1.441–1.780	<0.001***
Region	0: urban area, 1: rural area	2.419	2.152–2.720	<0.001***
BMI (kg/m^2)	+1 kg/m^2	1.141	1.124–1.158	<0.001***
Lumbar pain	0: absence, 1: presence	1.373	1.243–1.515	<0.001***
Lumbar pain (presence vs. absence)				
Age (years)	+1 year	1.018	1.013–1.023	<0.001***
Gender	0: men, 1: women	1.130	1.023–1.248	0.016*
Region	0: urban area, 1: rural area	2.016	1.801–2.256	<0.001***
BMI (kg/m^2)	+1 kg/m^2	1.020	1.003–1.031	0.021*
Knee pain	0: absence, 1: presence	1.375	1.246–1.518	<0.001***

BMI body mass index
* $p < 0.05$, *** $p < 0.001$

(2,800,000 men and 4,000,000 women) aged ≥40 years would be affected by both knee pain and lumbar pain.

To test the association between the knee pain and lumbar pain, the presence of knee pain was first used as an objective variable (0: absence, 1: presence) and age (+1 year), gender (men vs. women), BMI (+1 kg/m^2), regional differences (0: rural areas including Wakayama-1, Wakayama-2, Niigata, Mie, Akita, and Gunma vs. 1: urban areas including Tokyo-1, Tokyo-2, and Hiroshima), and lumbar pain (0: no, 1: yes) were used as explanatory variables. Then, the presence of lumbar pain was used as an objective variable (0: absence, 1: presence) and age (+1 year), gender (men vs. women), BMI (+1 kg/m^2), regional differences (0: rural areas including Wakayama-1, Wakayama-2, Niigata, Mie, Akita, and Gunma vs. 1: urban areas including Tokyo-1, Tokyo-2, and Hiroshima), and knee pain (0: no, 1: yes) were used as explanatory variables. Table 4 shows the result of the logistic regression analysis. Higher age, female sex, higher BMI, living in a rural area, and the presence of lumbar pain significantly influenced the presence of knee pain. Similarly, higher age, female sex, higher BMI, living in a rural area, and the presence of knee pain significantly influenced the presence of lumbar pain.

Discussion

In the present study, we integrated the information of individual cohorts established for the prevention of musculoskeletal diseases, and created the nationwide large-scale cohorts comprising the LOCOMO study. By using the data of the LOCOMO study, we found that the prevalence of knee pain was 32.7 % and that of lumbar pain was 37.7 %. Both knee pain and lumbar pain were prevalent in 12.2 % of the total population. In the present study, we also clarified that the factors associated with knee or lumbar pain were age, sex, body build, and residential characteristics. In addition, the presence of knee pain affected the lumbar pain, and vice versa. This association remained even after the adjustment for the above-mentioned associated factors. To our knowledge, this is the first study to report the frequency of the knee pain and lumbar pain and to estimate the total number of prevalent subjects, by using a large-scale population-based cohort study in Japan.

With regard to musculoskeletal pain, several population-based epidemiological studies have demonstrated that chronic pain is a highly prevalent condition. Soni et al. [14] reported that the prevalence rates of self-reported knee pain using the baseline data in 1,003 participants from the Chingford Women's Study were 22.97 % in the left knee and 24.80 % in the right knee. The definition of the presence of the knee pain (based on the following two questions: 'Have you had any knee pain in either knee in the last month?' and 'How many days of pain have you experienced in the last month?') was similar but not identical to our definition used in the LOCOMO study, and the subjects' age was younger in the Chinford study than in the LOCOMO study. Therefore, we could not compare the prevalence between the Chinford and LOCOMO studies directly. However, at a glance, the prevalence seems to be higher in the Japanese population. This may be due to the fact that the prevalence of KOA (KL grades ≥2) was higher in the Japanese population than that in the Caucasian population [15]. Verhaak et al. [16] reviewed epidemiological studies on chronic benign pain among adults, including subjects aged between 18 and 75 years, and reported that the prevalence ranged between 2 and 40 % of the population. Coggon et al. did not perform a population-based study, but instead conducted a cross-sectional survey comparing the prevalence of disabling low back pain and disabling wrist/hand pain among groups of workers carrying out similar physical activities in different cultural environments in 18 countries including Japan. They reported that the 1-month prevalence of disabling low back pain in nurses ranged from 9.6 to 42.6 %, and that of disabling wrist/hand pain in office workers ranged from 2.2 to 31.6 % [17]. We could not compare our results to those of Coggon's results directly because of the difference in the characteristics of the targeted population. However, previous reviews and reports demonstrated that the prevalence of the chronic pain varied in the population surveyed, and therefore, estimating the prevalence and number of patients in pain would require a study that comprises various regions with a large number of subjects. Our LOCOMO study contains 12,019 participants from the cohorts consisting of nine communities in different locations in Japan. Therefore, we believe that our estimation of the prevalence of knee pain and lumbar pain is appropriate, and the number of patients was sufficient.

With regard to the characteristics of subjects with chronic pain, Soni et al. [14] reported that among subjects who could be followed up for 12 years, a higher BMI was predictive of persistent knee pain (odds ratio = 1.14) and incident knee pain (odds ratio = 1.10). Verhaak et al. [16] demonstrated that chronic pain generally increased with age, with some studies reporting a peak prevalence between the ages of 45 and 65 years. These results were not consistent with our results. Moreover, we noted that living in a rural area was associated with the presence of knee pain and lumbar pain, which may be due to the difference of the primary occupation in that area. Muraki et al. [18] reported that the presence of KOA and LS was influenced by the primary occupation of the participants. According to their report, the prevalence of higher K/L grades of KOA and LS was significantly higher among agricultural, forestry, and fishery workers than among clerical workers and technical experts [18]. For occupational activities, sitting on a chair had a significant inverse association with K/L grades $\geq$2 for KOA and LS, whereas standing, walking, climbing and heavy lifting were associated with higher K/L grades for KOA [18]. An association between occupational activities and KOA was also observed in several studies [19–21]. Agricultural, forestry, and fishery workers seemed to be more common in rural areas than in urban areas. In addition, occupational activities, such as sitting on a chair, might be observed more commonly in clerical workers than in agricultural, forestry, and fishery workers. These findings might support the regional differences of pain that were observed in the present study. The main focus of the present study was pain, and not OA; however, the most probable diagnosis underlying knee pain among older people was reported to be OA [22].

There are also several reports regarding the coexistence of pain. The above-mentioned Coggon's investigation indicated that the rates of disabling pain at 2 anatomical sites—the lumbar spine and wrist/hand—covaried ($r = 0.76$) [17]. In their cross-sectional study, Smith et al., examined the presence and sites of chronic pain in 11,797 women. The presence of chronic pain was noted in 38 % of women; among them, the percentage of women experiencing chronic pain at 1, 2, 3, 4, and $\geq$5 sites was 23.2, 24.4, 20.0, 14.3, and 18.2 %, respectively [23]. These results showed that chronic pain coexists at other anatomical sites. In the present study, the prevalence of both knee pain and lumbar pain was 12.2 % (10.9 % in men and 12.8 % in women) among the general population. However, among the subjects with lumbar pain, 37.3 % also had knee pain (39.0 % in men and 36.6 % in women). Unfortunately, in the LOCOMO study, we were unable to collect the data regarding pain at anatomical sites other than knee pain and lumbar pain. Nevertheless, the coexistence of pain was commonly noted, which is inconsistent with previous reports.

There were several limitations in the present study. First, the current subjects do not truly represent the entire Japanese population. We should carefully consider this limitation, especially when determining the generalisability of the results. However, the LOCOMO study is the first large-scale population-based prospective study with more than 12,000 participants. Although it does not comprise the whole population of Japan, the number of participants in the cohorts established for the prevention of the musculoskeletal diseases appears to be biggest worldwide. Second, all the items of our survey in the baseline examination were not recorded in all cohorts. For example, radiographic examination of knees was performed only in Tokyo-1, Wakayama-1, Wakayama-2, Niigata, and Mie prefectures and radiographic examination of the lumbar spine was performed only in Tokyo-1, Wakayama-1, Wakayama-2, Hiroshima, and Mie prefectures. Third, the radiographic findings for OA assessment using KL scales have not been integrated yet, because of the delay in the standardisation of reading methods of the observers. Radiographs should be assessed by a single observer to omit the inter-observer variability, and if this is impossible, then the inter-observer variability among observers should be tested using the standardised criteria. Therefore, in the present study, we could not evaluate the severity of knee/spinal OA or vertebral fractures for assessing knee pain and lumbar pain. After suitable evaluation of intra-observer and inter-observer variability in the assessment of radiography findings and integration of this information, we hope to re-analyse the factors associated with the presence of chronic pain. Moreover, not only OA and fractures, but also rheumatoid arthritis and spondyloarthritis should be considered as parameters for assessing knee pain and lumbar pain. Although collection of the information on the diagnosis may be difficult on a large scale due to the associated cost, it may be possible to obtain this information in at least two cohorts.

In addition, our study has several strengths. First, as mentioned above, the large number of the integrated subjects included in the LOCOMO study is the biggest strength of this study. Moreover, we collected data from nine cohorts across Japan. By using the data of the LOCOMO study, we could compare the regional differences of specific clinical symptoms such as knee pain or lumbar pain, or particular diseases, such as KOA, LS, or OP, as well as its prognosis, such as the incidence of disability or mortality. In particular, we identified regional differences in the prevalences of knee pain and lumbar pain. In addition, we collected a substantial amount of information, via an interviewer-administered questionnaire, dietary assessment, anthropometric measurements, neuromuscular function assessment, biochemical measurements, medical history recording, radiographic assessment, and BMD measurement. However, all items were not recorded in all cohorts and the regional selection bias in each examination should be considered when interpreting the results.

In summary, by using the data of the LOCOMO study, we clarified the prevalence of knee pain and lumbar pain, their coexistence, and their associated factors.

Acknowledgments This work was supported by grants from Grant-in-Aid for H17-Men-eki-009 (Director, Kozo Nakamura), H20-Chou-jyu-009 (Director, Noriko Yoshimura), H23-Choujyu-002 (Director, Toru Akune), and H-25-Chojyu-007 (Director, Noriko Yoshimura) of the Ministry of Health, Labour and Welfare; and Scientific Research B23390172, B20390182, and Challenging Exploratory Research 24659317 to Noriko Yoshimura, B23390357 and C20591737 to Toru Akune, and B23390356 and C20591774, Challenging Exploratory Research 23659580 to Shigeyuki Muraki, Challenging Exploratory Research 24659666, 21659349 and Young Scientists A18689031 to Hiroyuki Oka, and Collaborating Research with NSF 08033011-00262 (Director, Noriko Yoshimura) from the Ministry of Education, Culture, Sports, Science and Technology in Japan. The sponsors did not contribute to the study design, data collection, data analysis, data interpretation, or the writing of the report.

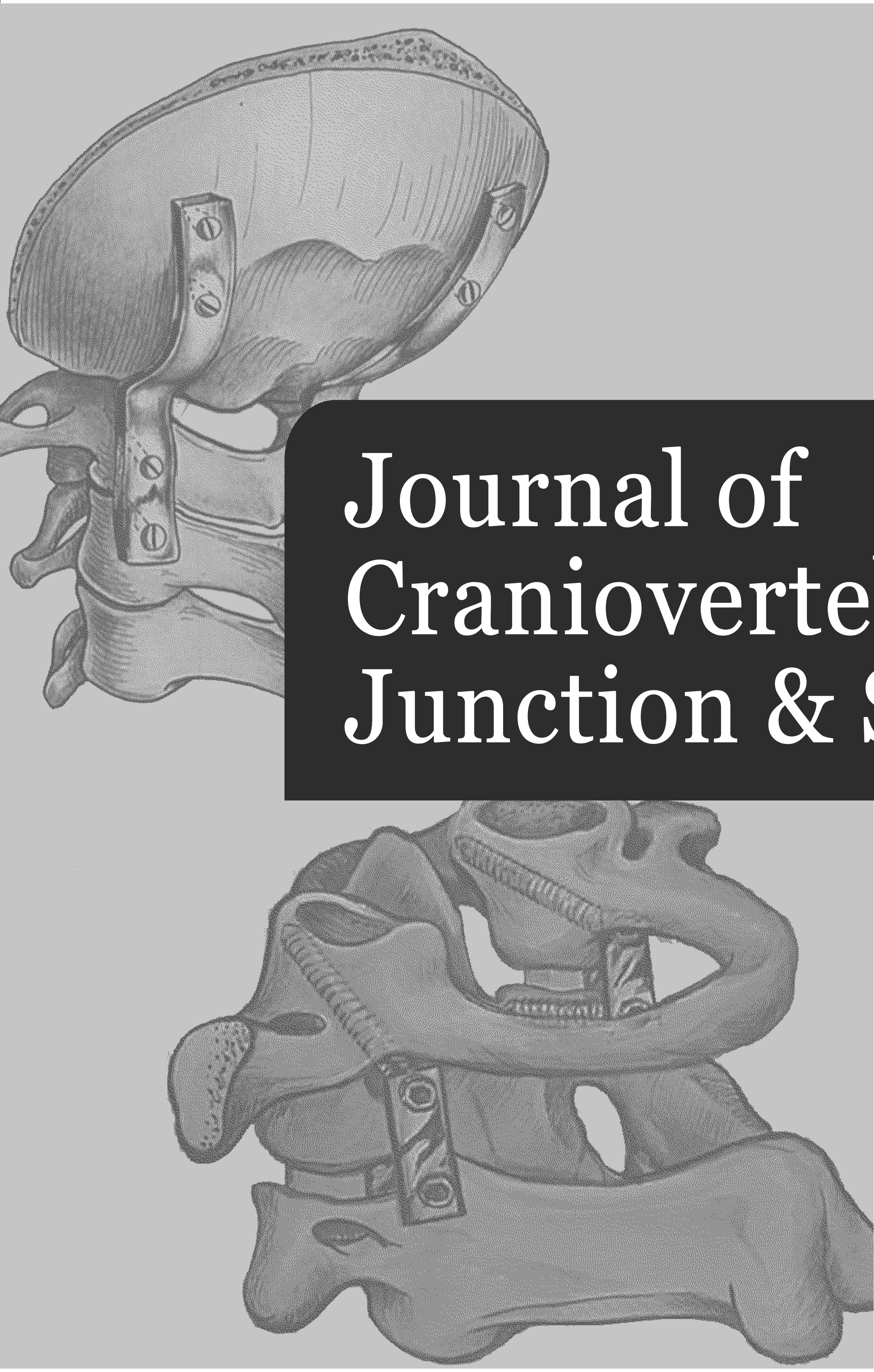
Conflict of interest The authors wish to thank Ms. Kyoko Yoshimura, Mrs. Toki Sakurai, and Mrs. Saeko Sahara for their assistance with data reduction and administration.

References

1. Ministry of Health, Labour and Welfare. Outline of the results of National Livelihood Survey 2010. http://www.mhlw.go.jp/toukei/saikin/hw/k-tyosa/k-tyosa10/4-2.html
2. Muraki S, Yamamoto S, Ishibashi H, Nakamura K (2006) Factors associated with mortality following hip fracture in Japan. J Bone Miner Metab 24:100–104
3. Yoshimura N, Muraki S, Oka H, Mabuchi A, En-Yo Y, Yoshida M, Saika A, Yoshida H, Suzuki T, Yamamoto S, Ishibashi H, Kawaguchi H, Nakamura K, Akune T (2009) Prevalence of knee osteoarthritis, LS and osteoporosis in Japanese men and women: the Research on Osteoarthritis/Osteoporosis Against Disability study. J Bone Miner Metab 27:620–628
4. Yoshimura N, Nakamura K, Akune T, Fujiwara S, Shimizu Y, Yoshida H, Omori G, Sudo A, Nishiwaki Y, Yoshida M, Shimokata H (2013) The longitudinal cohorts of motor system organ (LOCOMO) study (In Japanese). Nippon Rinsho 71:642–645
5. Orwoll E, Blank JB, Barrett-Connor E, Cauley J, Cummings S, Ensrud K, Lewis C, Cawthon PM, Marcus R, Marshall LM, McGowan J, Phipps K, Sherman S, Stefanick ML, Stone K (2005) Design and baseline characteristics of the osteoporotic fractures in men (MrOS) study: a large observational study of the determinants of fracture in older men. Contemp Clin Trials 26:569–585
6. Bellamy N, Buchanan WW, Goldsmith CH, Campbell J, Stitt LW (1998) Validation study of WOMAC. A health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. J Rheum 15:1833–1840
7. Johnson JA, Coons SJ, Ergo A, Szava-Kovats G (1998) Valuation of EuroQOL (EQ-5D) health states in an adult US sample. Pharmacoeconomics 13:421–433
8. Fukuhara S, Suzukao Y (2004) Manual of the SF-8 Japanese version. Institute for Health Outcomes & Process Evaluation Research, Kyoto
9. Teng EL, Chui HC (1987) The Modified Mini-Mental State (3MS) examination. J Clin Psychiatry 48:314–318
10. Kellgren JH, Lawrence LS (1957) Radiological assessment of osteoarthrosis. Ann Rheum Dis 16:494–502
11. World Health Organization (1994) Assessment of fracture risk and its application to screening for postmenopausal osteoporosis. WHO Technical Report Series 843, Geneva
12. Orimo H, Hayashi Y, Fukunaga M, Sone T, Fujiwara S, Shiraki M, Kushida K, Miyamoto S, Soen S, Nishimura J, Oh-Hashi Y, Hosoi T, Gorai I, Tanaka H, Igai T, Kishimoto H, Osteoporosis Diagnostic Criteria Review Committee: Japanese Society for Bone and Mineral Research (2001) Diagnostic criteria for primary osteoporosis: year 2000 revision. J Bone Miner Metab 19:331–337
13. Portal site of Official Statistics of Japan. Population Census 2010. http://www.e-stat.go.jp/SG1/estat/GL08020103.do?_toGL08020103_&tclassID=000001034991&cycleCode=0&requestSender=search
14. Soni A, Kiran A, Hart DJ, Leyland KM, Goulston L, Cooper C, Javaid MK, Spector TD, Arden NK (2012) Prevalence of reported knee pain over twelve years in a community-based cohort. Arthritis Rheum 64:1145–1152
15. Muraki S, Oka H, Akune T, Mabuchi A, En-yo Y, Yoshida M, Saika A, Suzuki T, Yoshida H, Ishibashi H, Yamamoto S, Nakamura K, Kawaguchi H, Yoshimura N (2009) Prevalence of radiographic knee osteoarthritis and its association with knee pain in the elderly of Japanese population-based cohorts: the ROAD study. Osteoarthr Cartil 17:1137–1143
16. Verhaak PF, Kerssens JJ, Dekker J, Sorbi MJ, Bensing JM (1998) Prevalence of chronic benign pain disorder among adults: a review of the literature. Pain 77:231–239
17. Coggon D, Ntani G, Palmer KT, Felli VE, Harari R et al (2013) Disabling musculoskeletal pain in working populations: is it the job, the person, or the culture? Pain 154:856–863
18. Muraki S, Akune T, Oka H, Mabuchi A, En-yo Y, Yoshida M, Saika A, Nakamura K, Kawaguchi H, Yoshimura N (2009) Association of occupational activity with radiographic knee osteoarthritis and LS in elderly patients of population-based cohorts: a large-scale population-based study. Arthr Rheum 61:779–786
19. Coggon D, Croft P, Kellingray S, Barrett D, McLaren M, Cooper C (2000) Occupational physical activities and osteoarthritis of the knee. Arthr Rheum 43:1443–1449

20. Felson DT (2004) An update on the pathogenesis and epidemiology of osteoarthritis. Radiol Clin North Am 42:1–9
21. Jensen LK (2008) Knee osteoarthritis: influence of work involving heavy lifting, kneeling, climbing stairs or ladders, or kneeling/squatting combined with heavy lifting. J Occup Environ Med 65:72–89
22. Duncan R, Peat G, Thomas E, Hay E, McCall I, Croft P (2007) Symptoms and radiographic osteoarthritis: not as discordant as they are made out to be? Ann Rheum Dis 66:86–91
23. Smith BH, Elliott AM, Hannaford PC, Royal College of General Practitioners' Oral Contraception Study (2004) Is chronic pain a distinct diagnosis in primary care? Evidence arising from the Royal College of General Practitioners' Oral Contraception Study. Fam Pract 21:66–74

ISSN 0974-8237



Journal of Craniovertebral Junction & Spine

www.jcvjs.com

Oct-Dec 2014 / Vol 5 / Issue 4

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Editor-in-Chief : Atul Goel (INDIA)
Open Access HTML Format
Journal of Craniovertebral Junction and Spine

Case Report

Occipitalized os odontoideum: A case report

Junich Ohya, Kota Miyoshi, Tomoaki Kitagawa, Shogo Nakagawa

Department of Orthopedic surgery, Yokohama Rosai Hospital, Yokohama, Japan

Corresponding author: Dr. Junichi Ohya, Department of Orthopaedic surgery, Faculty of Medicine, The University of Tokyo, Hongo 7-3-1, Bunkyo-ku, Tokyo, 113-0033, Japan.
E-mail: oyaj-ort@h.u-tokyo.ac.jp

Journal of Craniovertebral Junction and Spine 2014, 5:42

Abstract

We report on a 36-year-old man presenting with a sudden onset of motor weakness and numbness in the upper extremities following a fall from a truck bed. Radiological findings demonstrated an os odontoideum and osseous continuity between the occiput and an ossicle, termed an “occipitalized os odontoideum.” The occipitalized ossicle and atlas moved as a functional unit from the body of the axis. He underwent atlantoasxial stabilization with an atlas lateral mass screw and axis pedicle screw. Eighteen months later, he remained free of symptoms and showed solid bone fusion. Atlantoaxial stabilization resulted in an excellent clinical outcome for this condition. Our report provides useful knowledge regarding treatment of extremely rare osseous anomalies in the craniovertebral junction.

Key words: Atlantoaxial instability, os odontoideum, occipitalized atlas, spinal cord injury

INTRODUCTION

An os odontoideum is a rare condition in the craniovertebral junction (CVJ) which can cause mild progressive myelopathy or sudden spinal cord injury even after minor trauma.[1] Here, we report our experience with a patient who had a spinal cord injury due to atlantoaxial instability secondary to os odontoideum associated with an osseous continuity between the occiput and an ossicle, which was termed an “occipitalized os odontoideum.” To our knowledge, this is the first report describing an occipitalized os odontoideum.

CASE REPORT

A 36-year-old man presented with sudden motor weakness and numbness in the upper extremities following a fall from a truck bed. Neurological examination revealed motor weakness (grade 4/5) in his left triceps and intrinsic muscles. He had decreased sensation in both hands. He had intact cranial nerves and hyperreflexia in the left upper extremity with a positive Hoffmann sign. Knee and ankle reflexes were also abnormally increased bilaterally, with positive Babinski signs. A spastic gait and clumsiness of his hands were also noted. He denied any bowel or bladder difficulties.

Plain lateral radiographs showed an os odontoideum, and atlantoaxial instability was demonstrated during flexion-extension [Figure 1] Reconstruction computed tomography (CT) images demonstrated osseous continuity between the occiput and an ossicle, termed as “occipitalized os odontoideum.” The occipitalized ossicle and atlas moved as a functional unit from the body of the axis [Figure 2]. Magnetic resonance imaging (MRI) demonstrated intramedullary high signal intensity changes at the posterior arch of the atlas [Figure 3a]. High signal-intensity changes without spinal cord compression suggest the presence of focal spinal cord contusion due to instability between the cranial unit and the body of the axis.

The patient underwent uncomplicated atlantoaxial stabilization with an atlas lateral mass screw and axis pedicle screw. The bone graft harvested from the iliac crest was interposed between the posterior arc of atlas and the lamina of the axis. His post-operative

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course was uneventful. His symptoms, including motor weakness and sensory disturbance, improved shortly after surgery. At the 8-month follow-up examination, he had no symptoms, and dynamic lateral radiographs showed stabilization between the atlas and axis. MRI revealed that the intramedullary high-intensity lesion had disappeared [Figure 3b]. At month 18, he remained free of symptoms and showed solid bone fusion [Figure 4].

DISCUSSION

An os odontoideum is defined as the dissociation between the body of the axis and the dens, such that a disconnected ossicle takes the place of an intact odontoid process.[2] Surgical treatments, such as posterior atlantoaxial fixation with an atlas lateral mass screw and axis pedicle screw, have been reported as the mainstay of treatment for the patients who have os odontoideum and show neurological symptoms. They have also been reported, on occasion, to be a preventive treatment for spinal cord injury in patients without neurological symptoms.[1,3,4] Although the choice of surgical procedures for patients with atlantoaxial instability depends on the pathology of the instability, the patients' individual anatomical features, and their comorbidity, pre-operative imaging in the craniovertebral junction may often show concomitant diseases or conditions, such as osseous anomalies,[5,6] vertebral artery anomalies,[7] and congenital disease.[8] Knowledge of the treatments for these coexisting states can help the surgeon to prevent intra-or post-operative complications. We reported a case of an occipitalized os odontoideum, which was an extremely rare osseous anomaly in CVJ, causing spinal cord injury following an accidental fall. Atlantoaxial fixation was performed, which resulted in an excellent clinical outcome for this condition. We believe that our experience provide a basis for the selection of surgical procedure in this rare condition in CVJ.

The surgical stabilization of the os odontoideum with atlantoaxial fusion involving transarticular screw fixation or atlas lateral mass and axis pedicle fixation with polyaxial screws and rods have been described as mainstay surgical treatments. However, in this special condition, the main fear was that atlantoaxial fixation with atlas lateral mass screws and axis pedicle screws alone might be insufficient to fix the cranial unit consisting of the occipitalized ossicle and atlas with the axis. Pre-operative imaging revealed instability between the unit and the body of the axis, not atlantodental or occipitoatlas instability. Hence, we chose to perform atlantoaxial stabilization and not occipitocervical fixation. Two previous reports regarding surgical

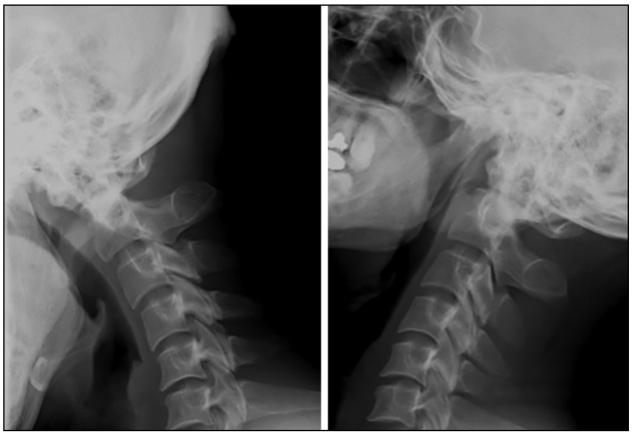

Figure 1: Lateral radiographs of cervical spine showing an osodontoideum and atlantoaxial instability during flexion-extension

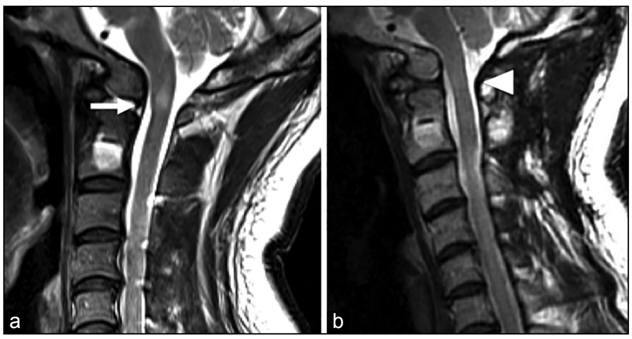

Figure 3: (a) Pre-operative sagittal T2-weighted magnetic resonance image demonstrating intramedullary high signal-intensity changes at the posterior arc of the atlas. High signal-intensity changes between the cranial unit and the body of the axis without spinal cord compression (arrow) suggest the presence of instability at the level (b) Post-operative sagittal T2-weighted magnetic resonance image showing that the intramedullary high signal-intensity changes at the posterior arc of the atlas had disappeared (arrowhead)

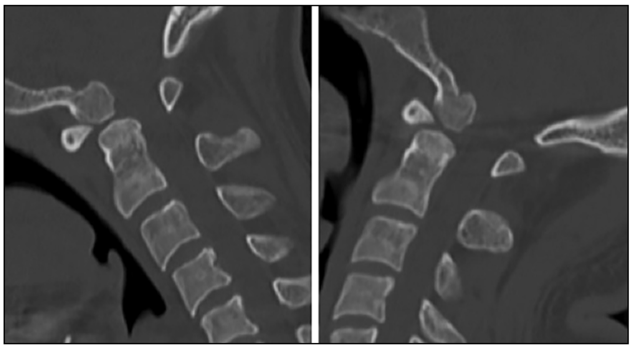

Figure 2: Sagittal reconstruction computed tomography showing an osseous continuity between occiput and an ossicle

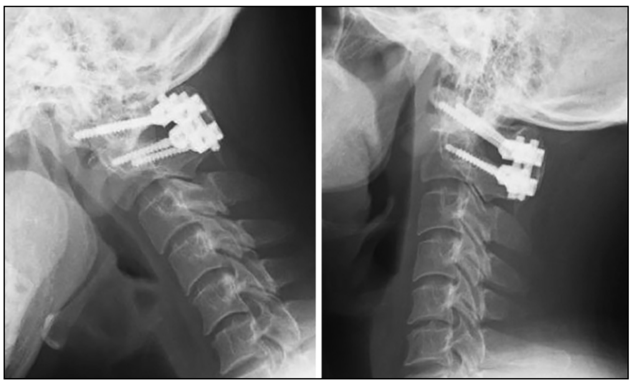

Figure 4: Post-operative flexion/extension lateral radiographs of cervical spine showing rigid fixation between atlas and axis

treatment for atlantoaxial instability with an occipitalized atlas, resembling the current case with the presence of a fused cranial unit, have been published. Jain *et al.*[9] performed occipitoaxial posterior fusion for 46 patients having congenital atlantoaxial dislocation with an occipitalized atlas. After that, Goel *et al.*[10] reported eight patients with an occipitalized atlas who had a mobile and reducible atlantoaxial dislocation and underwent lateral mass plate and screw fixation instead of fixation of the much longer plates or rods necessary for occipitocervical fixation. The method could be used even in the situation where the facet of the atlas is occipitalized. This latter report supports our consideration that the shortest fixation for the extent of instability is the ideal intervention. Use of atlantoaxial fixation, instead of occipitoaxial fixation, has the advantage that it can provide stabilization in the anteroposterior direction, while still preserving the flexion-extension motion between the cranial unit and the body of the axis. Although occipitoaxial fixation for this condition seems to be a reasonable strategy for surgical treatment, the longer fixation can spoil the flexion-extension motion and increase the mobility and loading at the inferior adjacent segment.

REFERENCES

1. Klimo P Jr, Kan P, Rao G, Apfelbaum R, Brockmeyer D. Os odontoideum: Presentation, diagnosis, and treatment in a series of 78 patients. J Neurosurg Spine 2008;9:332-42.
2. Klimo P Jr, Rao G, Brockmeyer D. Congenital anomalies of the cervical spine. Neurosurg Clin N Am 2007;18:463-78.
3. Arvin B, Fournier-Gosselin MP, Fehlings MG. Os odontoideum: Etiology and surgical management. Neurosurgery 2010;66:22-31.
4. Dai L, Yuan W, Ni B, Jia L. Os odontoideum: Etiology, diagnosis, and management. Surg Neurol 2000;53:106-8.
5. Ohya J, Chikuda H, Sugita S, Ono T, Oshima Y, Takeshita K, *et al.* Ossification of the posterior atlantoaxial membrane associated with an os odontoideum: A case report. J Orthop Surg (Hong Kong) 2011;19:392-4.
6. Weng C, Wang LM, Wang WD, Tan HY. Bipartite atlas with os odontoideum and synovial cyst: Case report and review literature. Spine (Phila Pa 1976) 2010;35:E568-75.
7. Yamazaki M, Okawa A, Furuya T, Sakuma T, Takahashi H, Kato K, *et al.* Anomalous vertebral arteries in the extraand intra-osseous regions of the craniovertebral junction visualized by 3-dimensional computed tomographic angiography: Analysis of 100 consecutive surgical cases and review of the literature. Spine (Phila Pa 1976) 2012;37:E1389-97.
8. Trabacca A, Dicuonzo F, Gennaro L, Palma M, Cacudi M, Losito L, *et al.* Os odontoideum as a rare but possible complication in children with dyskinetic cerebral palsy: A clinical and neuroradiologic study. J Child Neurol 2011;26:1021-5.
9. Jain VK, Mittal P, Banerji D, Behari S, Acharya R, Chhabra DK. Posterior occipitoaxial fusion for atlantoaxial dislocation associated with occipitalized atlas. J Neurosurg 1996;84:559-64.
10. Goel A, Kulkarni AG. Mobile and reducible atlantoaxial dislocation in presence of occipitalized atlas: Report on treatment of eight cases by direct lateral mass plate and screw fixation. Spine (Phila Pa 1976) 2004;29:E520-3.

How to cite this article: Ohya J, Miyoshi K, Ki! tagawa T, Nakagawa S. Occipitalized os odontoideum: A case report. J Craniovert Jun Spine 2014;5:170-2.

Source of Support: Nil, **Conflict of Interest:** None declared.

The Journal of Arthroplasty xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

Total Hip Arthroplasty After Rotational Acetabular Osteotomy

Hideya Ito, MD [a,b], Yoshio Takatori, MD, PhD [c], Toru Moro, MD, PhD [d], Hirofumi Oshima, MD [d], Hiroyuki Oka, MD [e], Sakae Tanaka, MD, PhD [b]

[a] Bone and Joint Orthopaedic Surgery, Japanese Red Cross Medical Center, Shibuya-ku, Tokyo, Japan
[b] Sensory and Motor System Medicine, Faculty of Medicine, The University of Tokyo, Bunkyo-ku, Tokyo, Japan
[c] Japan Community Health Care Organization Yugawara Hospital, Ashigara-gun, Kanagawa, Japan
[d] Division of Science for Joint Reconstruction, Graduate School of Medicine, The University of Tokyo, Bunkyo-ku, Tokyo, Japan
[e] Department of Joint Disease Research, 22nd Century medical and Research Center, Graduate, School of Medicine, The University of Tokyo, Bunkyo-ku, Tokyo, Japan

ARTICLE INFO

Article history:
Received 21 August 2014
Accepted 1 October 2014
Available online xxxx

Keywords:
rotational acetabular osteotomy
periacetabular osteotomy
acetabular dysplasia
total hip arthroplasty
acetabular cups

ABSTRACT

In this study, we aimed to determine whether the outcomes of total hip arthroplasty (THA) after rotational acetabular osteotomy (RAO) are equal to those of primary THA, and to elucidate the characteristics of THA after RAO. The clinical and radiographic findings of THA after RAO (44 hips), with minimum 24 months of follow-up, were compared with a matched control group of 58 hips without prior RAO. We found that the outcomes in terms of functional scores and complication rates did not differ between THA after RAO and THA without previous pelvic osteotomy, indicating that the results of THA after RAO are equivalent to those of primary THA. Although THA after RAO requires technical considerations, similar clinical outcomes to primary THA can be expected.

Rotational acetabular osteotomy (RAO) is a type of periacetabular osteotomy used to treat symptomatic dysplasia of the acetabulum [1]. This procedure involves restoration of the femoral head coverage, resulting in pain relief and delays or prevention of the onset of arthritis. In Japan, there are reportedly a higher proportion of patients with dysplastic hips than in other countries [2], and many of these patients have undergone RAO. While some studies have reported good results of RAO [3–6], some patients require subsequent total hip arthroplasty (THA) because of pain secondary to progression of arthritis.

Several reports are available on THA after periacetabular osteotomy [7–11]. Most authors reported that THA after periacetabular osteotomy requires technical consideration and careful radiographic evaluation because the acetabulum may undergo morphologic changes. In terms of clinical results, one study reported that Bernese periacetabular osteotomy does not compromise the outcome of THA [11], whereas another study reported that the outcomes of THA after triple innominate osteotomy were not equivalent to those of primary THA [8]. However, it should be noted that these studies all had small sample sizes or were not comparative studies. To date, only one published case report of THA after RAO is available [12], and the effects of a previous RAO on subsequent THA are still unknown.

In this study, we aimed to determine whether the outcomes of THA after RAO are equal to those of primary THA, and to elucidate the characteristics of THA after RAO by comparing the clinical and radiographic findings of patients who underwent THA after RAO with matched controls who underwent THA without prior RAO.

Materials and Methods

This investigation was a retrospective chart and radiographic review comparing two groups of patients. We obtained institutional ethics board approval for the study, which was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. All patients provided informed consent to participate in the study. Between 1999 and 2011, we performed THA on 45 hips in 43 patients who had previously undergone RAO. One patient was lost to follow-up, resulting in the study group comprising of 44 hips in 42 patients. For comparative purposes, 58 age- and gender-matched hips in 58 patients who had undergone THA for osteoarthritis secondary to hip dysplasia during same period were identified and included as the control group. None of the patients in the control group had undergone any prior pelvic osteotomy.

The preoperative data analyzed included age at THA, gender, interval from RAO to THA (years), body mass index (BMI), the Crowe classification [13] of hip joints, pre-THA contralateral hip joint status, and previous femoral osteotomy. Post-operative data comprised the follow-up duration after THA.

Conflict of interest statement: One of the co-author receives finance as a consultant for Msd K. K., Asahi Kasei Pharma Corporation, Teijin Pharma Limited, Daiichi Sankyo Company, Limited, and has also received finance for presentations at Eisai Co., Ltd., Ono Pharmaceutical Co., Ltd., Taisho Toyama Pharmaceutical Co., Ltd., Chugai Pharmaceutical Co., Ltd., Eli Lilly Japan K. K., Pfizer Japan Inc., Msd K. K., Asahi Kasei Pharma Corporation, Teijin Pharma Limited, Daiichi Sankyo Company, Limited.

The Conflict of Interest statement associated with this article can be found at http://dx.doi.org/10.1016/j.arth.2014.10.002.

Reprint requests: Hideya Ito, MD, Bone and Joint Orthopaedic Surgery, Japanese Red Cross medical Center, 4-1-22 Hiroo Shibuya-ku, Tokyo 150-8935, Japan.

http://dx.doi.org/10.1016/j.arth.2014.10.002
0883-5403/

Please cite this article as: Ito H, et al, Total Hip Arthroplasty After Rotational Acetabular Osteotomy, J Arthroplasty (2014), http://dx.doi.org/10.1016/j.arth.2014.10.002

Surgical Procedure

All THAs were performed in the lateral decubitus position and through a posterior approach. The incision used differed from that used in the preceding RAO, which had been performed through a combined anterior and posterior approach with a single incision, as described by Ninomiya et al [1]. We used the combined approach described by Lusskin et al [14] for 35/44 hips in the study group and 42/58 hips in the control group. We did not perform trochanteric osteotomy in any joints. We attempted to place the acetabular cup with an abduction angle of between 30° and 50° [15]. After the acetabular preparation, the center of reaming was decided, and a gouge was used to remove the subchondral bone to measure the distance to the medial wall. Initial medialization of the acetabular reaming was performed using the smallest reamer, after which the diameter of the reamer was gradually increased. When there was uniform contact between the reamer and acetabular bone, a cup of that size was selected. All patients received a cementless acetabular component with 4 fins and additional screw fixation if required. After the final femoral reaming and rasping, trial reduction was performed. If a bony impingement occurred, any osteophytes of the acetabulum were removed using a chisel or bone rongeur forceps luer. Upon resolving the bony impingement, the final implantation of the femoral component was performed. All femoral components used were also cementless devices. The Mallory-Head acetabular and Bimetric stem systems (Biomet, Warsaw, IN, USA) were used on 32 hips in the study group and 38 hips in the control group, whereas the Q5LP acetabular and K-MAX stem systems (Kyocera Medical Corp, Osaka, Japan) were used in 12 and 20 hips in the study and control groups, respectively.

Computed tomography (CT) scans were obtained in all patients in the study group in order to determine the three-dimensional shape of the acetabulums.

Operative Data and Clinical Evaluation

Operative data, including the operative time, intraoperative estimated blood loss, removal of osteophytes, and the size of acetabular cups used, were obtained using clinical records.

Hip joint function was evaluated according to the Merle d'Aubigné-Postel score [16] preoperatively and at the final follow-up. Reoperation and complications, including infection, venous thromboembolism, dislocation, nerve palsy, and wound healing problems, were recorded.

Radiographic Evaluation

Radiographic evaluations were performed using anteroposterior radiographs taken before and immediately after THA, and at the final follow-up. The acetabular cup position was evaluated on the radiographs obtained immediately post-surgery. We measured the abduction angle of the acetabular cup and the hip joint center position. The hip joint center position was defined as the vertical and horizontal distances from the teardrop, as described by Fukui et al [17] (Fig. 1). The magnification of each radiograph was calibrated from the known and measured diameters of the prosthetic femoral head. Loosening of the acetabular cup and heterotopic bone formation were evaluated on the radiographs obtained immediately post-THA and at the final follow-up. The acetabular cup was considered to be loosening if there was more than 3 mm of migration or a change of at least 4° in the abduction angle [18]. We used the classification system developed by Brooker et al [19] to qualitatively evaluate heterotopic bone formation.

Statistical Analysis

Statistical analysis of the differences between the study and control groups was conducted using JMP Pro 10.0 (SAS Institute, Cary, NC, USA). The independent-sample t test was used for continuous variables, whereas the chi-square test or Fisher's exact test was used for dichotomous values according to the validity conditions. All statistical tests were two-tailed, and a significance level of 0.05 was used.

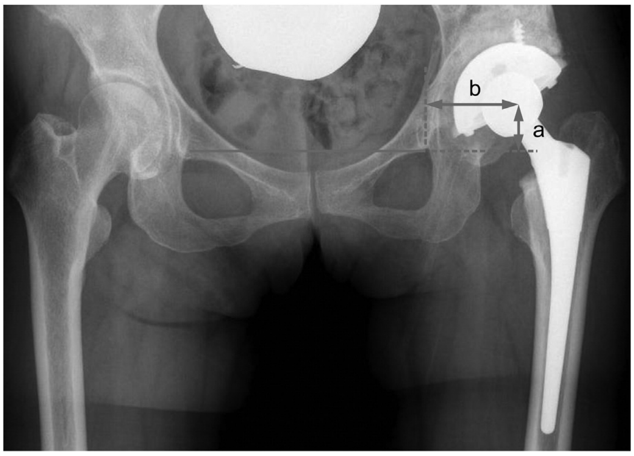

Fig. 1. Measurement of hip joint center position. The hip joint center position was defined as the vertical distance (a) and horizontal distance (b) from the teardrop.

Results

Demographics

The demographic and clinical baseline data of the patients are shown in Table 1. The mean age at the time of THA, gender, BMI, previous femoral osteotomy, and follow-up duration did not differ significantly between the two groups. Furthermore, the ratio of the Crowe classification of the preoperative hip joints and the contralateral hip joint status were also not significantly different between the groups. The average time interval between RAO and THA was 21 years (range, 7–37 years).

Operative Data and Clinical Evaluation

The operative and clinical data are shown in Table 2. The operative time in the study group was significantly longer than in the control

Table 1
Baseline Characteristics of the Study Patients (n = 100).

	Study Group	Control Group	*P*
Number of hips	44	58	
Number of patients	42	58	
Gender (M/F)	2/40	2/56	
Age at RAO (years)	34 ± 12.4 (11–53)	N/A	
Age at THA (years)	55.6 ± 7.8 (36–72)	56 2 ± 5.1 (46–67)	0.64
Interval from RAO to THA (years)	21 ± 7.3 (7–37)	N/A	
BMI (kg/m^2)	22.8 ± 3.4 (17.3–32.0)	22.3 ± 2.7 (17.5–27.6)	0.65
Crowe classification			0.87
I	29 (66.0%)	39 (67.3%)	
II	10 (22.7%)	14 (24.1%)	
III	3 (6.8%)	4 (6.9%)	
IV	2 (4.5%)	1 (1.7%)	
Contralateral joint			0.77
Normal	14 (31.8%)	21 (38.1%)	
OA	20 (45.5%)	27 (46.6%)	
THA	10 (22.7%)	10 (17.2%)	
Previous femoral osteotomy	2 (4.5%)	4 (6.9%)	1.00
Follow-up (months)	55.8 ± 36.2 (24–107)	62.9 ± 28.4 (24–95)	0.06

Data are presented as mean ± standard deviation (range) or number (%). Abbreviations: M, male; F, female; RAO, rotational acetabular osteotomy; THA, total hip arthroplasty; N/A, not applicable; BMI, body mass index; OA, osteoarthritis.

Please cite this article as: Ito H, et al, Total Hip Arthroplasty After Rotational Acetabular Osteotomy, J Arthroplasty (2014), http://dx.doi.org/10.1016/j.arth.2014.10.002

Table 2
Operative Data and Clinical Evaluations.

	Study Group (n = 44)	Control Group (n = 58)	*P*
Operative time (min)	177 ± 41 (115–227)	161 ± 36 (91–206)	0.03[a]
Blood loss (g)	567 ± 232 (140–1445)	524 ± 254 (50–1710)	0.15
Osteophyte removal	40 (90.9%)	31 (53.4%)	<0.001[a]
Combined approach	35 (79.5%)	42 (72.4%)	0.33
Cup size (mm)	50 ± 3.2 (46–58)	48 ± 2.1 (46–54)	<0.001[a]
MA score (preoperative)			
Total	8.3 ± 1.7 (5–12)	8.4 ± 2.1 (4–13)	0.74
Pain	2.3 ± 0.7 (1–4)	2.2 ± 0.8 (1–4)	0.26
Mobility	3.2 ± 1.2 (1–6)	3.6 ± 1.3 (1–6)	0.04[a]
Walking	2.8 ± 0.8 (1–5)	2.7 ± 0.8 (1–5)	0.31
MA score (last follow-up)			
Total	15.2 ± 1.7 (11–18)	15.7 ± 1.8 (11–18)	0.12
Pain	5.3 ± 0.6 (4–6)	5.5 ± 0.6 (4–6)	0.05
Mobility	5.1 ± 0.9 (3–6)	5.4 ± 0.8 (3–6)	0.12
Walking	4.8 ± 0.8 (3–6)	4.8 ± 1 (2–6)	0.78
Complications			
Infection	0	1	1.00
VTE	0	2	1.00
Dislocation	0	0	1.00
Nerve palsy	0	0	1.00
Wound healing problems	0	0	1.00
Reoperation	0	1	1.00

Data are presented as mean ± standard deviation (range) or number (%). Abbreviations: MA, Merle d'Aubigné-Postel; VTE, venous thromboembolism.
[a] $P < 0.05$.

group ($P = 0.029$); however, there were no differences in the estimated blood loss. In 40/44 hips (90.9%) in the study group, removal of osteophytes of the acetabular anterior wall was performed because of bony impingement, whereas this procedure was performed in only 31/58 hips (53.4%) in the control group.

The mean diameter of the acetabular cup used was 50 mm (range, 46–58 mm) in the study group, and 48 mm (range, 46–54 mm) in the control group ($P < 0.001$). There were no differences in the preoperative total Merle d'Aubigné-Postel score between the groups; however, the mobility score in the study group was significantly lower than in the control group ($P = 0.043$). At the last follow-up, the total Merle d'Aubigné-Postel, pain, mobility, and walk scores in the study and control groups were significantly improved compared with the preoperative scores. However, no significant differences were observed between the groups in terms of the improvements in the clinical results from before THA and the last follow-up. Reoperation was not needed for any patient. Postoperative complications included one case of infection and 2 cases of venous thromboembolism in the control group, whereas there were no cases of dislocation, wound healing problems, or nerve palsy.

Radiographic Evaluation

The radiographic data are shown in Table 3. The mean acetabular cup abduction angles were 40.7° (range, 30°–52°) and 43.5° (range, 22°–66°) in the study and control groups, respectively. Outliers of acetabular cup abduction angle were one hip >50° in the study group, and 10 hips >50° in the control group ($P = 0.021$).

The mean vertical distances of the hip joint center position after THA were 25.7 mm (range, 11–40 mm) and 23.7 mm (range, 13–41 mm) in the study and control groups, respectively. The mean horizontal distances were 31.2 mm (range, 21–42 mm) and 28.1 mm (range, 19–37 mm) in the study and control groups, respectively. While there was no significant difference in the vertical distance, the horizontal distance in the study group was found to be significantly larger than in the control group ($P = 0.002$), suggesting that the acetabular cup of THA after RAO was placed laterally. Moreover, there was no loosening of the acetabular and femoral component in either group. Heterotopic bone formations were seen in 15/44 hips (34.1%) (Grade I: 11 hips, Grade II: 3 hips, and grade III: 1 hip) in the study group and in 6/58 hips (10.3%) (Grade I: 6 hips) in the control group ($P = 0.008$).

Table 3
Radiographic Evaluations.

	Study Group (n = 44)	Control Group (n = 58)	*P*
Loosening	0	0	
Heterotopic ossification			0.008[a]
0	29 (65.9%)	52 (89.7%)	
1	11 (25%)	6 (10.3%)	
2	3 (7.0%)	0 (0%)	
3	1 (2.3%)	0 (0%)	
Cup abduction (°)	40.7 ± 5.2 (30–52)	43.5 ± 8.2 (22–66)	0.02[a]
Hip joint center			
Vertical distance (mm)	25.7 ± 6.5 (11–40)	23.7 ± 5.7 (13–41)	0.09
Horizontal distance (mm)	31.2 ± 5.3 (21–42)	28.1 ± 3.8 (19–37)	0.002[a]

Data are presented as mean ± standard deviation (range) or number (%).
[a] $P < 0.05$.

Discussion

In this study, we demonstrated that the results of THA after RAO were comparable to those of primary THA, and reported on 7 specific characteristics of THA after RAO. We found that the outcomes in terms of the functional scores and complication rates did not differ between THA after RAO and THA without previous pelvic osteotomy, indicating that the results of THA after RAO are equivalent to those of primary THA. The characteristics of THA after RAO (study group) were as follows: the preoperative range of hip motion was poorer, the operative time was longer, the acetabular cups used were larger, removal of osteophytes was needed in more cases, heterotopic bone formations after THA were seen more frequently, the abduction angles of the acetabular cups were smaller, and their position tended to be lateral.

In most patients, removal of large osteophytes was needed after RAO, and we speculate that the presence of osteophytes might be associated with a poorer preoperative range of hip joint motion. In turn, removal of the osteophytes and the poor hip joint motion might be responsible for the prolonged operation time observed in the study group. Moreover, the acetabular cups used in the study group were larger than in the control group, indicating that the acetabulums after RAO may become wider than before RAO.

Interestingly, the abduction angles of the acetabular cups were lower in the study group than those in the control group. The abduction angles of 43/44 (97.7%) acetabular cups in the study group were within the target range, compared to only 48/58 (82.8%) acetabular cups in the control group. All outliers were >50°. These data indicated that the acetabular cups in the control group were occasionally placed too steep, likely because of the presence of acetabular dysplasia [20]. Correction of acetabular dysplasia by RAO may help surgeons place the acetabular cups in an adequate abduction angle. The acetabular cup position in the study group tended to be more lateralized than in the control group. Kaneuji et al [21] reported that the normal hip joint center was 31.5 ± 5 mm lateral from the teardrop. While the acetabular cup position in our study seemed to be largely acceptable, it has been recognized that acetabular cups in the upper and lateral position may lead to poor results during THA [22–24]. The appropriate cup position depends on the position and shape of the acetabulum, and RAO prior to THA may influence the cup position. Thus, this should be evaluated both during the preoperative planning and intraoperatively.

Although anteversion of the acetabular component was not measured in the present study, signs of retroversion of the acetabulum after periacetabular osteotomy have been previously reported [11], and preoperative CT is effective for three-dimensional evaluations of the acetabulum and osteophyte (Fig. 2).

Please cite this article as: Ito H, et al, Total Hip Arthroplasty After Rotational Acetabular Osteotomy, J Arthroplasty (2014), http://dx.doi.org/10.1016/j.arth.2014.10.002

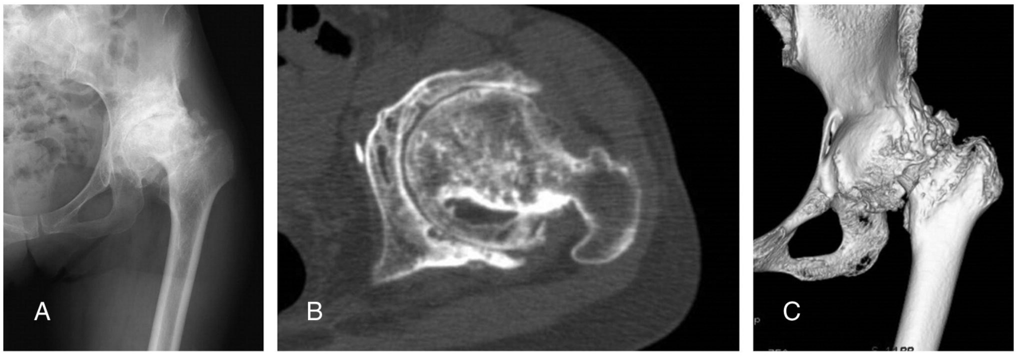

Fig. 2. The preoperative left hip of a 63-year-old woman with osteoarthritis after rotational acetabular osteotomy. (A) Anteroposterior radiograph showing progressive osteoarthritis changes. (B) Axial computed tomography image showing a large osteophyte of the acetabulum needing removal, and the depth of the acetabulum. (C) Three-dimensional computed tomography image showing the three-dimensional shape of the acetabulum.

In the present study, heterotopic bone formations after THA were seen more frequently in the study group (34.1%) than in the control group (10.3%). Similarly, previous studies reported that heterotopic bone formations were seen in 10%–42% of cases of THA after periacetabular osteotomy [10,11]. However, since most cases were classed as stage I or II in this study, heterotopic bone formations did likely not affect the clinical outcomes [25]. Moreover, we were concerned that wound healing problems would occur in the study group, since two separate incisions were performed, however, this did not occur in any case. We often used the combined approach in cases with poor range of hip motion or large osteophytes needing removal, and did not have to use trochanteric osteotomy in any case, suggesting that the approach is useful for exposing the anterior hip joint. Although we did not use any cemented devices or reinforced rings in this study, no component was loose. Thus, standard cementless devices appear to be useful in THA after RAO.

Previous studies have shown that RAO for dysplastic hips results in short-term hip pain relief and intermediate-term prevention of progression of arthritis, and the present study showed that the results of THA after RAO are equivalent to those of primary THA. Accordingly, we believe that RAO followed by THA could have long-term effects and result in long-term maintenance of the hip joint function for young patients with dysplastic hips, and longer follow-up studies are needed to confirm this.

In previous studies on the topic, the average time interval between a preceding periacetabular osteotomy and THA has been reported to range between 3.3 and 7.5 years [7,8,10,11]. In the present study, the average time interval between RAO and THA was 21 years. Thus, our results suggest that RAO may be a good procedure of joint preservation for dysplasia of the acetabulum. However, further large-scale studies are still needed in the future to investigate which periacetabular osteotomy procedure preserves the joint for the longest duration

This study has several limitations, including its retrospective nature and relatively short follow-up period. Moreover, three-dimensional radiographic evaluation was not performed.

In conclusion, although THA after RAO requires technical considerations, similar clinical outcomes to primary THA can be expected. However, further large-scale, long-term studies using three-dimensional radiographs are needed in the future to confirm our findings.

References

1. Ninomiya S, Tagawa H. Rotational acetabular osteotomy for the dysplastic hip. J Bone Joint Surg Am 1984;66:430.
2. Yoshimura N, Campbell L, Hashimoto T, et al. Acetabular dysplasia and hip osteoarthritis in Britain and Japan. Br J Rheumatol 1998;37:1193.
3. Ninomiya S. Rotational acetabular osteotomy for the severely dysplastic hip in the adolescent and adult. Clin Orthop Relat Res 1989;247:127.
4. Nakamura S, Ninomiya S, Takatori Y, et al. Long-term outcome of rotational acetabular osteotomy: 145 hips followed for 10–23 years. Acta Orthop Scand 1998;69:259.
5. Okano K, Enomoto H, Osaki M, et al. Outcome of rotational acetabular osteotomy for early hip osteoarthritis secondary to dysplasia related to femoral head shape: 49 hips followed for 10–17 years. Acta Orthop 2008;79:12.
6. Takatori Y, Ninomiya S, Nakamura S, et al. Long-term results of rotational acetabular osteotomy in patients with slight narrowing of the joint space on preoperative radiographic findings. J Orthop Sci 2001;6:137.
7. Baqué F, Brown A, Matta J. Total hip arthroplasty after periacetabular osteotomy. Orthopedics 2009;32:399.
8. Peters CL, Beck M, Dunn HK. Total hip arthroplasty in young adults after failed triple innominate osteotomy. J Arthroplasty 2001;16:188.
9. Wozniak W, Nikratowicz P, Owczarski T, et al. Total hip arthroplasty following Ganz periacetabular osteotomy. Cases study. Ortop Traumatol Rehabil 2010;12:561.
10. Hartig-Andreasen C, Stilling M, Søballe K, et al. Is cup positioning challenged in hips previously treated with periacetabular osteotomy? J Arthroplasty 2014;29:763.
11. Parvizi J, Burmeister H, Ganz R. Previous Bernese periacetabular osteotomy does not compromise the results of total hip arthroplasty. Clin Orthop Relat Res 2004;423:118.
12. Shinoda S, Hasegawa Y, Kawabe K, et al. Total hip arthroplasty for failed rotational acetabular osteotomy: a report of three cases. Nagoya J Med Sci 1998;61:53.
13. Crowe JF, Mani VJ, Ranawat CS. Total hip replacement in congenital dislocation and dysplasia of the hip. J Bone Joint Surg Am 1979;61:15.
14. Lusskin R, Goldman A, Absatz M. Combined anterior and posterior approach to the hip joint in reconstructive and complex arthroplasty. J Arthroplasty 1988;3:313.
15. Lewinnek GE, Lewis JL, Tarr R, et al. Dislocations after total hip-replacement arthroplasties. J Bone Joint Surg Am 1978;60:217.
16. D'Aunigné RM, Postel M. Functional results of hip arthroplasty with acrylic prosthesis. J Bone Joint Surg Am 1954;36:451.
17. Fukui K, Kaneuji A, Sugimori T, et al. A radiological study of the true anatomical position of the acetabulum in Japanese women. Hip Int 2011;21:311.
18. Massin P, Schmidt L, Engh CA. Evaluation of cementless acetabular component migration. An experimental study. J Arthroplasty 1989;4:245.
19. Brooker AF, Bowerman JW, Robinson RA, et al. Ectopic ossification following total hip replacement. Incidence and a method of classification. J Bone Joint Surg Am 1973;55:1629.
20. Rittmeister M, Callitsis C. Factors influencing cup orientation in 500 consecutive total hip replacements. Clin Orthop Relat Res 2006;445:192.
21. Kaneuji A, Sugimori T, Ichiseki T, et al. Minimum ten-year results of a porous acetabular component for Crowe I to III hip dysplasia using an elevated hip center. J Arthroplasty 2009;24:187.
22. Pagnano W, Hanssen AD, Lewallen DG, et al. The effect of superior placement of the acetabular component on the rate of loosening after total hip arthroplasty. J Bone Joint Surg Am 1996;78:1004.
23. Doehring TC, Rubash HE, Shelley FJ, et al. Effect of superior and superolateral relocations of the hip center on hip joint forces. An experimental and analytical analysis. J Arthroplasty 1996;11:693.
24. Morag G, Zalzal P, Liberman B, et al. Outcome of revision hip arthroplasty in patients with a previous total hip replacement for developmental dysplasia of the hip. J Bone Joint Surg (Br) 2005;87:1068.
25. Kocic M, Lazovic M, Mitkovic M, et al. Clinical significance of the heterotopic ossification after total hip arthroplasty. Orthopedics 2010;33:16.

Please cite this article as: Ito H, et al, Total Hip Arthroplasty After Rotational Acetabular Osteotomy, J Arthroplasty (2014), http://dx.doi.org/10.1016/j.arth.2014.10.002

J Orthop Sci (2015) 20:71–77
DOI 10.1007/s00776-014-0669-1

ORIGINAL ARTICLE

Prospective multicenter surveillance and risk factor analysis of deep surgical site infection after posterior thoracic and/or lumbar spinal surgery in adults

Satoshi Ogihara · Takashi Yamazaki · Toru Maruyama · Hiroyuki Oka · Kota Miyoshi · Seiichi Azuma · Takashi Yamada · Motoaki Murakami · Naohiro Kawamura · Nobuhiro Hara · Sei Terayama · Jiro Morii · So Kato · Sakae Tanaka

Received: 24 July 2014 / Accepted: 16 October 2014 / Published online: 1 November 2014

Abstract

Background Surgical site infection is a serious and significant complication after spinal surgery and is associated with high morbidity rates, high healthcare costs and poor patient outcomes. Accurate identification of risk factors is essential for developing strategies to prevent devastating infections. The purpose of this study was to identify independent risk factors for surgical site infection among posterior thoracic and/or lumbar spinal surgery in adult patients using a prospective multicenter surveillance research method.

Methods From July 2010 to June 2012, we performed a prospective surveillance study in adult patients who had developed surgical site infection after undergoing thoracic and/or lumbar posterior spinal surgery at 11 participating hospitals. Detailed preoperative and operative patient characteristics were prospectively recorded using a standardized data collection format. Surgical site infection was based on the definition established by the Centers for Disease Control and Prevention.

Results A total of 2,736 consecutive adult patients were enrolled, of which 24 (0.9%) developed postoperative deep surgical site infection. Multivariate regression analysis indicated four independent risk factors. Preoperative steroid therapy ($P = 0.001$), spinal trauma ($P = 0.048$) and gender (male) ($P = 0.02$) were statistically significant independent

S. Ogihara (✉)
Department of Orthopaedic Surgery, Sagamihara National Hospital, 18-1 Sakuradai, Minami-ku, Sagamihara City, Kanagawa 252-0392, Japan
e-mail: s-ogihara@sagamihara-hosp.gr.jp

T. Yamazaki · S. Terayama
Department of Orthopaedic Surgery, Musashino Red Cross Hospital, Tokyo, Japan

T. Maruyama
Department of Orthopaedic Surgery, Saitama Medical Center, Saitama Medical University, Saitama, Japan

H. Oka
Department of Joint Disease Research, 22nd Century Medical and Research Center, Faculty of Medicine, The University of Tokyo, Tokyo, Japan

K. Miyoshi
Department of Orthopaedic Surgery, Yokohama Rosai Hospital, Kanagawa, Japan

S. Azuma
Department of Orthopaedic Surgery, Saitama Red Cross Hospital, Saitama, Japan

T. Yamada
Department of Orthopaedic Surgery, NTT Kanto Hospital, Tokyo, Japan

M. Murakami
Department of Orthopaedic Surgery, Toranomon Hospital, Tokyo, Japan

N. Kawamura
Department of Spine and Orthopaedic Surgery, Japanese Red Cross Medical Center, Tokyo, Japan

N. Hara · S. Tanaka
Department of Orthopaedic Surgery, Faculty of Medicine, University of Tokyo, Tokyo, Japan

J. Morii
Department of Orthopaedic Surgery, Sanraku Hospital, Tokyo, Japan

S. Kato
Department of Orthopaedic Surgery and Musculoskeletal Oncology, Tokyo Metropolitan Komagome Hospital, Tokyo, Japan

patient-related risk factors, whereas an operating time ≥3 h ($P < 0.001$) was a surgery-related independent risk factor.

Conclusion Preoperative steroid therapy, spinal trauma, male gender and an operating time ≥3 h were independent risk factors for deep surgical site infection after thoracic and/or lumbar spinal surgery in adult patients. Identification of these risk factors can be used to develop protocols aimed at decreasing the risk of surgical site infection.

Introduction

Surgical site infection (SSI) after spinal surgery is one of the most serious complications that occurs in 0.7–12% of patients and can lead to high morbidity, mortality and increased healthcare costs [1, 2]. In this regard, various risk factors for SSI have been investigated to prevent this devastating complication. Risk factors were separated into two main categories: patient-related risk factors and surgery-related risk factors. Patient-related risk factors include advanced age [3], male gender [4], obesity [5, 6], previous spinal surgery [5], diabetes [5–7], malnutrition [3], smoking [5], spinal trauma [8, 9] and corticosteroid use [5, 10]. Surgery-related risk factors include spinal instrumentation [11], posterior surgical approach [2], tumor resection [2], fusion extending to the sacrum [12], increased estimated blood loss [4, 7] and prolonged operating time [4, 11, 13]. However, many of these studies were performed retrospectively at individual institutions, and they are limited by their relatively small sample size that restricts the power to perform a multivariate analysis.

High quality studies based on a prospective design and a large sample size are required to identify precise independent risk factors for SSI following spinal surgery. Multivariate analysis should also be performed to adjust for the occurrence of multiple risk factors within individual patients. In addition, standardized, hospital-based, multicenter surveillance methods utilizing a standard definition of SSI have been recommended to help determine risk factors and are considered useful in reducing infection rates [14–16].

Therefore, the purpose of this study was to identify independent risk factors for adult patients who develop deep SSI after posterior thoracic and/or lumbar spinal surgery using a prospective multicenter surveillance research method.

Materials and methods

Study design and selection criteria

This surveillance study for SSI following posterior thoracic and/or lumbar spinal surgery in adult patients was conducted in a prospective manner from July 1, 2010 to June 30, 2012 at 11 participating Japanese hospitals. Patients included in the study had undergone surgery by orthopedic service only. Each patient had undergone follow-up for a minimum of one year. Detailed preoperative patient characteristics and operative characteristics were recorded prospectively using a standardized data collection format. The institutional review board at participating hospitals approved the present study and informed consent was obtained from each patient. Patients who underwent surgery for the treatment of spinal infection were excluded from the present analysis. For homogeneity of the study group, we also excluded patients aged <20 years, those who underwent posterior instrumentation removal, vertebroplasty (percutaneous or open surgery), endoscopic surgery or single-stage anterior-posterior surgery.

Identification of SSI

A patient was considered to have an infection on the basis of the SSI definition put forth by the Centers for Disease Control and Prevention [17]. Superficial SSI was defined as an infection occurring within 30 days after the operation and involving the skin or subcutaneous tissue only. Deep SSI was defined as an infection occurring within 30 days after the operation if no implant was left in place or within one year if the implant was left in place, if the infection appeared to be operation-related and involved deep soft tissues. A deep SSI was further characterized by the presence of one or more of the following [17]: (1) purulent drainage from the deep incision; (2) a deep incision spontaneously dehisces or is deliberately opened by a surgeon when the patient has at least one of the following signs or symptoms: fever (>38 °C), localized pain, or tenderness, unless the site is culture-negative; (3) an abscess or other evidence of infection involving the deep incision that is found on direct examination, during reoperation or by a histopathologic or radiologic examination; and (4) diagnosis of a deep incisional SSI by a surgeon or attending physician.

The incidence of SSI was confirmed after double-checking by the attending surgeons and colleagues involved in this study at the participating hospitals. Microbiologic culture results of each patient with deep SSI were recorded and assembled. In cases in which open debridement was performed, microbiologic cultures were taken to confirm the presence of SSI and to determine further treatment.

Data collection

At each study hospital, the medical records of eligible adult patients who had undergone posterior thoracic and/or lumbar spinal procedures were prospectively collected utilizing standardized patient charts.

The recorded preoperative patient characteristics included age at time of surgery, sex, height, weight and diagnosis (spinal trauma, disc herniation, spinal stenosis, tumor or cancer, inflammatory arthritis, osteoporosis or spinal deformity). Preoperative patient-related risk factors for SSI included smoking, diabetes mellitus, body mass index (BMI), the patient's American Society of Anesthesiologists (ASA) score [18], previous surgery and steroid use. In addition, surgery-related factors considered as possible risk factors for SSI were collected and analyzed. These included operating time, estimated blood loss, anatomic location (thoracic, lumbar and/or sacral), emergency surgery, use of instrumentation, iliac crest bone grafting, dural tear and use of intraoperative fluoroscopy.

Statistical analysis

Associations between deep SSI and potential risk factors were analyzed. Fisher's exact test was used for categorical variables and the Wilcoxon test was used for continuous variables. Multivariate analysis was performed to evaluate the risk factors for SSI. Significant variables and the variables that correlated ($P < 0.20$) with SSI in univariate analysis were entered into a stepwise multiple logistic regression model. Furthermore, to adjust for confounding factors, the BMI and anatomic location of the surgery were entered into this model, as in previous reports BMI [5, 6] and anatomic location of the surgery [12] were identified as risk factors of SSI after spinal surgeries. All analyses were performed using SPSS Statistics version 19 (IBM Corporation, Armonk, NY) with the significance threshold set at $P < 0.05$.

Results

From July 2010 to June 2012, a total of 2,736 consecutive patients (1,164 female, 1,572 male; mean age, 64.6 years; age range, 20–94 years) in 11 Japanese hospitals were enrolled. Overall, 24 patients (0.9%) developed postoperative deep SSI. The demographic characteristics of the patients included in the study are shown in Table 1.

The statistical relationships of all variables to deep SSI are reported in Table 2. Univariate analysis indicated several significant risk factors, including an ASA score ≥3, preoperative steroid use, spinal trauma, spinal instrumentation, use of intraoperative fluoroscopy and an operating time ≥3 h. The significant factors in the univariate analysis and the factors with a P value <0.20 in the univariate analysis (male sex, diabetes mellitus, previous surgery and emergency surgery) were included in a multivariate analysis to further examine the risk factors for deep SSI. Although the BMI and anatomic location of the surgery were not significantly associated with deep SSI in the univariate analysis, they were included in the multivariate models. The final multivariate model shown in Table 2 is the most parsimonious model, showing the independent risk factors for deep SSI after adjusting for other risk factors. According to logistic regression models, men had a higher risk of deep SSI than women [odds ratio (OR), 3.01; 95% confidence interval (CI), 1.15–8.94; $P = 0.02$]. The preoperative diagnosis was also found to be associated with an increased risk of SSI; patients with spinal trauma had a 4.04 times higher risk than patients with other diagnoses (95% CI, 1.01–14.49; $P = 0.048$). Patients with preoperative steroid therapy (oral intake) had an 8.53 times higher risk than patients without steroid therapy (95% CI, 2.49–25.82; $P = 0.001$). An operating time ≥3 h was also found to be significantly associated with an increased risk of SSI (OR, 10.28; 95% CI, 3.31–39.36; $P < 0.0001$).

Microbiologic cultures were routinely taken in all 24 patients who developed deep SSI and 87.5% (21/24) of the patients had a positive culture. Twenty-one of the 24 patients (87.5%) underwent open debridement. In three patients, no organisms were isolated; antibiotics were administered intravenously prior to open debridement in these three patients, after which open debridement was performed. Abscess formation in the deep soft tissues was observed in the thee patients. Twenty of 21 patients with positive cultures (95.2%) had a single organism isolated, while only one case demonstrated polymicrobacterial growth [methicillin-resistant *Staphylococcus aureus* (MRSA) + *Propionibacterium acnes*]. *Staphylococcus aureus* was present in 57.1% (12/21) of the positive cultures (including the case of polymicrobacterial growth), with 66.7% (8/12) of these isolates demonstrating MRSA. Coagulase-negative *Staphylococcus* was the next most common organism, with occurrence in 33.3% (7/21) of the positive cultures; methicillin resistance was noted in 71.4% (5/7) of the patients (Table 3).

Discussion

In this study, we identified independent risk factors for adult patients who develop a deep SSI after posterior thoracic and/or lumbar spinal surgery using a prospective multicenter surveillance research method. An operating time ≥3 h was the strongest independent risk factor for postoperative deep SSI after adjusting for all other variables. This result is consistent with those of previous studies that described a prolonged surgical procedure as a significant risk factor for SSI [4, 13]. Frequent release of the tension on self-retractors [13] can minimize tissue ischemia and necrosis caused by intraoperative wound retraction during long-duration operations. A longer operating time also

Table 1 Demographic characteristics of the patients included in the study

Characteristics	Deep SSI ($n = 24$)	Non-deep SSI ($n = 2{,}712$)	P value[a]
Age at surgery, mean (SD), year	67.5 (13.2)	64.0 (15.0)	0.34
Male, *n* (%)	18 (75.0)	1,554 (57.3)	0.08
BMI, mean (SD), kg/m^2	23.9 (3.3)	23.8 (3.6)	0.88
ASA score, *n* (%)			
1 and 2	18 (75.0)	2,462 (90.8)	0.008
$\geq$3	6 (25.0)	250 (9.2)	
Diabetes mellitus, *n* (%)	5 (20.8)	308 (11.4)	0.14
Smoking, *n* (%)	4 (16.7)	332 (12.2)	0.51
Preoperative steroid therapy (oral intake), *n* (%)	5 (20.8)	89 (3.3)	<0.0001
Previous surgery, *n* (%)	7 (29.2)	420 (15.5)	0.07
Diagnosis, *n* (%)			
Spinal trauma	5 (20.8)	117 (4.3)	<0.0001
Other	19 (79.2)	2,595 (95.7)	
Anatomic location of the surgery, *n* (%)			
Sacrum included	2 (8.3)	212 (7.8)	0.72
Other	22 (91.7)	2,500 (92.2)	
Surgical variables, *n* (%)			
Instrumentation	18 (75.0)	1,388 (51.2)	0.02
Emergency surgery	3 (12.5)	107 (4.0)	0.03
Use of intraoperative fluoroscopy	4 (16.7)	135 (5.0)	0.009
Dural tear	3 (12.5)	274 (10.1)	0.70
Iliac crest bone graft	3 (12.5)	215 (8.0)	0.41
Operating time $\geq$3 h	20 (83.3)	952 (35.1)	<0.0001

ASA American Society of Anesthesiologists, *BMI* body mass index, *SSI* surgical site infection

[a] Fisher's exact test was used for categorical variables and the Wilcoxon test was used for continuous variables

increases the risk for bacterial contamination in the surgical wounds [19]; frequent saline irrigation of the surgical wound during the procedure can help prevent this complication [9].

Preoperative steroid use as a risk factor for SSI has been described in several previous studies on spinal surgery patients [5, 10]. On the other hand, there are other studies reporting that steroid use was not a risk factor for SSI [2, 6]. In our study, multivariate analysis showed a strong association between preoperative steroid therapy (oral intake) and postoperative deep SSI. Many of these previous studies were conducted at individual hospitals and, to our knowledge, this is the first study evaluating the association between preoperative steroid therapy and SSI following spinal surgery using a prospective multicenter design. There appears to be a paucity of literature on the relationship between steroid dosage and SSI following spinal surgeries and steroid dosage was not included in our study. For a more detailed evaluation of steroid use and SSI risk, additional high-quality research is needed in the future.

Several studies have reported on patients with spinal trauma and the incidence of SSI [8, 9, 20]. Watanabe et al. reported a strong association between trauma and SSI using multivariate analysis, as compared to patients who underwent elective surgery (OR, 9.42; 95% CI, 1.59–55.73) [9]. The results of our analysis are consistent with previous reports. Patients with a traumatized spine tend to include multisystem trauma, concomitant open wounds, head injury and/or cardiopulmonary instability. Since multisystem trauma can cause severe general conditions, the preoperative hospital stay for patients with spinal trauma tends to be long. Blam et al. [8] reported that surgical treatment of the spine >160 h after injury increased the incidence of infection by more than 8 times, compared with cases in which treatment began within 48 h after injury. Blam et al. [8] also reported that the duration of the postoperative intensive care unit stay was an independent significant risk factor for SSI. In patients with a traumatized spine, it is important to perform the surgery immediately after general conditions are stabilized and decrease the perioperative stay in the intensive care unit.

Male gender was also found to be significantly associated with an increased risk of deep SSI in our current multivariate analysis, even though it was not significant in the univariate analysis. To our knowledge, only one previous study found a statistically significant association between being male and SSI after spinal surgery [4], but this relationship has been reported in several studies on total knee arthroplasty [21, 22] and gastric surgery [23]. In order to evaluate the association of the male gender with SSI more precisely, additional prospective studies with large sample sizes are needed.

Table 2 Univariate and multivariate logistic regression analyses for the odds ratios (ORs) and 95 % confidence interval (CI) of risk factors for deep SSI

Demographic characteristics	Univariate		Multivariate	
	OR (95 % CI)	*P* value	OR (95 % CI)	*P* value
Sex				
Female	1.00	0.07	1.00	0.02
Male	2.24 (0.93–6.18)		3.01 (1.15–8.94)	
BMI				
+1 kg/m^2	0.99 (0.90–1.11)	0.88	0.98 (0.88–1.10)	0.69
ASA score				
1 and 2	1.00	0.02	1.00	0.42
≥ 3	3.28 (1.81–7.91)		1.55 (0.51–4.13)	
Diabetes mellitus				
Yes	2.05 (0.68–5.15)	0.19	1.16 (0.36–3.14)	0.78
No	1.00		1.00	
Smoking				
Yes	1.43 (0.41–3.82)	0.53		
No	1.00			
Preoperative steroid therapy (oral intake)				
Yes	7.76 (2.53–19.80)	0.001	8.53 (2.49–25.82)	0.001
No	1.00		1.00	
Previous surgery				
Yes	2.25 (0.86–5.24)	0.16	2.03 (0.73–5.15)	0.16
No	1.00		1.00	
Diagnosis				
Spinal trauma	5.84 (1.91–14.81)	0.037	4.04 (1.01–14.49)	0.048
Other	1.00		1.00	
Anatomic location of the surgery				
Sacrum included	1.07 (0.17–3.67)	0.49	1.00	0.49
Other	1.00		1.42 (0.24–1.87)	
Instrumentation				
Yes	2.86 (1.20–7.91)	0.017	1.70 (0.50–5.31)	0.38
No	1.00		1.00	
Emergency surgery				
Yes	3.48 (0.81–10.29)	0.085	2.93 (0.51–12.58)	0.21
No	1.00		1.00	
Use of intraoperative fluoroscopy				
Yes	3.81 (1.10–10.29)	0.037	3.34 (0.90–9.92)	0.07
No	1.00		1.00	
Dural tear				
Yes	1.27 (0.29–3.72)	0.71		
No	1.00			
Iliac crest bone graft				
Yes	1.66 (0.39–4.86)	0.44		
No	1.00			
Operating time				
≥3 h	9.24 (3.49–31.85)	<0.0001	10.28 (3.31–39.36)	<0.0001
<3 h	1.00		1.00	

ASA American Society of Anesthesiologists, *BMI* body mass index, *SSI* surgical site infection

Contrary to some reports [11, 24], the use of instrumentation was not an independent risk factor for SSI in the current analysis. According to the univariate analysis, the use of instrumentation showed a significant association with deep SSI; however, the instrumentation and operating time factors may be confounding in relation to the occurrence of

Table 3 Microbiologic characteristics of deep SSI

Organism(s)	No. of cases
MRSA	7
Methicillin-resistant CNS	5
Staphylococcus aureus	4
CNS	2
Pseudomonas aeruginosa	1
Corynebacterium sp.	1
MRSA + *Propionibacterium acnes*	1
Unknown	3

CNS coagulase-negative staphylococci, *MRSA* methicillin-resistant *Staphylococcus aureus*, *SSI* surgical site infection

deep SSI in our data. In fact, the operating time was ≥3 h in all patients who received spinal instrumentation and developed deep SSI in the current study. Reducing the surgical time may help prevent SSI following posterior thoracolumbar instrumentation fusion surgery. However, in instrumentation surgery, biofilm formation and treatment difficulty in cases of deep wound infections have been reported [24]. Therefore, care and attention should be paid particularly to patients undergoing instrumentation surgery for the prevention of SSI.

Several reports have described diabetes as a risk factor for SSI after spinal surgeries [5–7]; however, diabetes was not a significant risk factor for deep SSI in the present study according to univariate and multivariate analyses. There is a possibility that the diabetes patients in our study included well-controlled and poor-controlled cases. Hikata et al. [7] reported that poorly-controlled diabetes (HbA1c $\geq$ 7.0%) was statistically significantly associated with the development of SSI after posterior thoracolumbar spinal instrumentation surgeries compared to well-controlled diabetes (6.1 $\leq$ HbA1c < 7.0%), and SSI occurred in none of the patients (0%) with well-controlled diabetes (6.1 $\leq$ HbA1c < 7.0%) in their operated case series.

Several studies have demonstrated that obesity is a patient-related risk factor for SSI [5, 6]; however, BMI was not a significant factor according to univariate and multivariate analyses in our study. Yoshiike et al. [25] reported that the prevalence of obesity in Japanese adults, which is estimated using international criteria (BMI $\geq$ 30), is lower than that of Western populations. Flegal et al. [26] described that 33.8% of adults in the United States were obese (BMI $\geq$ 30, 2007 to 2008); whereas, in our case series, 167 of 2,736 patients (6.1%) were obese. This difference in the prevalence of obesity between Japanese and Western populations may affect our study findings. Mahta et al. [27, 28] demonstrated that the thickness of subcutaneous fat at the surgical site was an important risk factor for SSI in posterior spine surgeries, and they described that the thickness of subcutaneous fat at the surgical site is more significant for predicting SSI than BMI.

No patients in our study underwent intrawound application of vancomycin powder, although recent studies have reported its effectiveness in preventing SSI after spinal surgery [29, 30]. In patients considered at high risk for SSI, the use of this treatment may be effective for reducing the incidence of devastating wound infections following spinal surgery.

A limitation of this study is the relatively small sample size of infected patients (n = 24), as only patients with deep SSI following specific types of procedures (posterior thoracic and/or lumbar surgery) were included. This contrasts with previous research on SSI that generally focused on a wide variety of spinal procedures and all types of infection [2, 6]. Another limitation is the fact that malnutrition and the number of the operated levels were not included in the factors we assessed. The occurrence of selection bias in patient enrollment cannot be denied; however, we made an effort to minimize this bias by enrolling consecutive patients from multiple centers and not from a single center. The strengths of this study are the relatively large number of surgical procedures. In addition, the prospective multicenter surveillance design allowed for a detailed study of independent risk factors for SSI after spinal surgery by using multivariate logistic regression.

In conclusion, we identified that an operative time ≥3 h, preoperative steroid use, spinal trauma and male gender were independent risk factors for deep SSI following posterior thoracic and/or lumbar spinal surgery in adult patients. The SSI risk factors identified in this study may facilitate the design of protocols for reducing the incidence of SSI in the future.

Conflict of interest The authors declare no conflicts of interest.

References

1. Xing D, Ma JX, Ma XL, Song DH, Wang J, Chen Y, Yang Y, Zhu SW, Ma BY, Feng R. A methodological, systematic review of evidence-based independent risk factors for surgical site infections after spinal surgery. Eur Spine J. 2013;22(3):605–15.
2. Olsen MA, Mayfield J, Lauryssen C, Polish LB, Jones M, Vest J, Fraser VJ. Risk factors for surgical site infection in spinal surgery. J Neurosurg. 2003;98(2 Suppl):149–55.
3. Klein JD, Hey LA, Yu CS, Klein BB, Coufal FJ, Young EP, Marshall LF, Garfin SR. Perioperative nutrition and postoperative complications in patients undergoing spinal surgery. Spine. 1996;21(22):2676–82.
4. Rao SB, Vasquez G, Harrop J, Maltenfort M, Stein N, Kaliyadan G, Klibert F, Epstein R, Sharan A, Vaccaro A, Flomenberg P. Risk factors for surgical site infections following spinal fusion procedures: a case-control study. Clin Infect Dis. 2011;53(7):686–92.
5. Wimmer C, Gluch H, Franzreb M, Ogon M. Predisposing factors for infection in spine surgery: a survey of 850 spinal procedures. J Spinal Disord. 1998;11(2):124–8.
6. Olsen MA, Nepple JJ, Riew KD, Lenke LG, Bridwell KH, Fraser VJ. Risk factors for surgical site infection following orthopaedic spinal operations. J Bone Joint Surg Am. 2008;90(1):62–9.

7. Hikata T, Iwanami A, Hosogane N, Watanabe K, Ishii K, Nakamura M, Kamata M, Toyama Y, Matsumoto M. High preoperative hemoglobin A1c is a risk factor for surgical site infection after posterior thoracic and lumbar spinal instrumentation surgery. J Orthop Sci. 2014;19(2):223–8.
8. Blam OG, Vaccaro AR, Vanichkachorn JS, Albert TJ, Hilibrand AS, Minnich JM, Murphey SA. Risk factors for surgical site infection in the patient with spinal injury. Spine. 2003;28(13):1475–80.
9. Watanabe M, Sakai D, Matsuyama D, Yamamoto Y, Sato M, Mochida J. Risk factors for surgical site infection following spine surgery: efficacy of intraoperative saline irrigation. J Neurosurg Spine. 2010;12(5):540–6.
10. Klekamp J, Spengler DM, McNamara MJ, Haas DW. Risk factors associated with methicillin-resistant staphylococcal wound infection after spinal surgery. J Spinal Disord. 1991;12(3):187–91.
11. Maragakis LL, Cosgrove SE, Martinez EA, Tucker MG, Cohen DB, Perl TM. Intraoperative fraction of inspired oxygen is a modifiable risk factor for surgical site infection after spinal surgery. Anesthesiology. 2009;110(3):556–62.
12. Picada R, Winter RB, Lonstein JE, Denis F, Pinto MR, Smith MD, Perra JH. Postoperative deep wound infection in adults after posterior lumbosacral spine fusion with instrumentation: incidence and management. J Spinal Disord. 2000;13(1):42–5.
13. Sasso RC, Garrido BJ. Postoperative spinal wound infections. J Spinal Disord. 2000;13(1):42–5.
14. Emori TG, Culver DH, Horan TC, Jarvis WR, White JW, Olson DR, Banerjee S, Edwards JR, Martone WJ, Gaynes RP, Hughes JM. National nosocomial infections surveillance system (NNIS): description of surveillance methods. Am J Infect Control. 1991;19(1):19–35.
15. Surveillance National Nosocomial Infections. (NNIS) report, data summary from October 1986-April 1996, issued May 1996. A report from the National Nosocomial Infections Surveillance (NNIS) System. Am J Infect Control. 1996;24(5):380–8.
16. Roberts FJ, Walsh A, Wing P, Dvorak M, Schweigel J. The influence of surveillance methods on surgical wound infection rates in a tertiary care spinal surgery service. Spine. 1998;23(3):366–70.
17. Mangram AJ, Horan TC, Pearson ML, Silver LC, Jarvis WR. Guideline for prevention of surgical site infection, 1999. Hospital Infection Control Practices Advisory Committee. Infect Control Hosp Epidemiol. 1999;20(4):250–78.
18. Owens WD, Felts JA, Spitznagel EL Jr. ASA physical status classifications: a study of consistency of ratings. Anesthesiology. 1978;49(4):239–43.
19. Ahn DK, Park HS, Kim TW, Yang JH, Boo KH, Kim IJ, Lee HJ. The degree of bacterial contamination while performing spine surgery. Asian Spine J. 2013;7(1):8–13.
20. Lim MR, Lee JY, Vaccaro AR. Surgical infections in the traumatized spine. Clin Orthop Relat Res. 2006;444:114–9.
21. Namba RS, Inacio MC, Paxton EW. Risk factors associated with deep surgical site infections after primary total knee arthroplasty: an analysis of 56,216 knees. J Bone Joint Surg Am. 2013;95(9):775–82.
22. Song KH, Kim ES, Kim YK, Jin HY, Jeong SY, Kwak YG, Cho YK, Sung J, Lee YS, Oh HB, Kim TK, Koo KH, Kim EC, Kim JM, Choi TY, Kim HY, Choi HJ, Kim HB. Differences in the risk factors for surgical site infection between total hip arthroplasty and total knee arthroplasty in the Korean Nosocomial Infections Surveillance System (KONIS). Infect Control Hosp Epidemiol. 2012;33(11):1086–93.
23. Kim ES, Kim HB, Song KH, Kim YK, Kim HH, Jin HY, Jeong SY, Sung J, Cho YK, Lee YS, Oh HB, Kim EC, Kim JM, Choi TY, Choi HJ, Kim HY. Prospective nationwide surveillance of surgical site infections after gastric surgery and risk factor analysis in the Korean Nosocomial Infections Surveillance System (KONIS). Infect Control Hosp Epidemiol. 2012;33(6):572–80.
24. Kasliwal MK, Tan LA, Traynelis VC. Infection with spinal instrumentation: review of pathogenesis, diagnosis, prevention, and management. Surg Neurol Int. 2013;4(Suppl 5):S392–403.
25. Yoshiike N, Matsumura Y, Zaman MM, Yamaguchi M. Descriptive epidemiology of body mass index in Japanese adults in a representative sample from the National Nutrition Survey 1990–1994. Int J Obes Relat Metab Disord. 1998;22(7):684–7.
26. Flegal KM, Carroll MD, Ogden CL, Curtin LR. Prevalence and trends in obesity among US adults, 1999–2008. JAMA. 2010;303(3):235–41.
27. Mehta AI, Babu R, Karikari IO, Grunch B, Agarwal VJ, Owens TR, Friedman AH, Bagley CA, Gottfried ON. The distribution of body mass as a significant risk factor for lumbar spinal fusion postoperative infections. Spine. 2012;37(19):1652–6.
28. Mehta AI, Babu R, Sharma R, Karikari IO, Grunch BH, Owens TR, Agarwal VJ, Sampson JH, Lad SP, Friedman AH, Kuchibhatla M, Bagley CA, Gottfried ON. Thickness of subcutaneous fat as a risk factor for infection in cervical spine fusion surgery. J Bone Joint Surg Am. 2013;95(4):323–8.
29. Sweet FA, Roh M, Sliva C. Intrawound application of vancomycin for prophylaxis in instrumented thoracolumbar fusions: efficacy, drug levels, and patient outcomes. Spine. 2011;36(24):2084–8.
30. Caroom C, Tullar JM, Benton EG Jr, Jones JR, Chaput CD. Intrawound vancomycin powder reduces surgical site infections in posterior cervical fusion. Spine. 2013;38(14):1183–7.

J Orthop Sci (2015) 20:64–70
DOI 10.1007/s00776-014-0666-4

ORIGINAL ARTICLE

Patient satisfaction with double-door laminoplasty for cervical compression myelopathy

Junichi Ohya · Yasushi Oshima · Katsushi Takeshita · Hiroyuki Oka · Hirotaka Chikuda · Yuki Taniguchi · Yoshitaka Matsubayashi · Sakae Tanaka

Received: 27 June 2014 / Accepted: 12 October 2014 / Published online: 30 October 2014

Abstract

Background Patient satisfaction with posterior laminoplasty for cervical compression myelopathy is not yet established. Moreover, postoperative patient-reported outcomes (PROs) associated with patient satisfaction remain unclear. This study aimed to investigate patient satisfaction after double-door laminoplasty for cervical compression myelopathy, and to identify the postoperative patient-reported outcomes associated with patient satisfaction.

Methods This retrospective study included 97 patients with cervical compression myelopathy who underwent double-door laminoplasty between 2002 and 2010 in our institution [mean follow-up: 58 months (range 12–123 months)]. We assessed postoperative PROs from questionnaires administered before surgery and at the latest follow-up. These questionnaires included the Neck Disability Index, physical and mental component summary of Short Form-36, EuroQol-5 dimension, Japanese Orthopaedic Association Cervical Myelopathy Evaluation Questionnaire (JOACMEQ), and a numerical rating scale of pain or numbness in the neck, arms, and scapular lesion. Satisfaction was evaluated on the basis of a seven-point scale. Patients were divided into two groups: satisfied (very satisfied, satisfied, slightly satisfied) and dissatisfied (neither satisfied nor dissatisfied, slightly dissatisfied, dissatisfied, very dissatisfied). All PROs and the effectiveness of surgical treatment assessed by JOACMEQ were compared between both groups.

Results The satisfied group comprised 69 patients (71 %). Univariate analysis revealed a significant difference in scapular pain, Neck Disability Index, physical component summary of Short Form-36, postoperative mental component summary of Short Form-36, and improvement of lower extremity function postoperatively between both groups. Multivariate analysis revealed that there was a significantly higher proportion of patients with improved lower extremity function in the satisfied group than in the dissatisfied group.

Conclusions In conclusion, 71 % of the patients who underwent double-door laminoplasty for cervical compression myelopathy were satisfied. The findings of this study, which examines the association between patient satisfaction and PROs, suggest that improvement in lower extremity function following surgical intervention affects patient satisfaction in those with cervical compression myelopathy.

J. Ohya (✉) · Y. Oshima · K. Takeshita · H. Chikuda · Y. Taniguchi · Y. Matsubayashi · S. Tanaka
Department of Orthopaedic Surgery, Faculty of Medicine, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
e-mail: oyaj-ort@h.u-tokyo.ac.jp

H. Oka
Department of Joint Disease Research, 22nd Century Medical and Research Center, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan

Introduction

Posterior laminoplasty has been established as one of the primary interventions in patients with cervical compression myelopathy due to cervical spondylotic changes and ossification of the posterior longitudinal ligament (OPLL) [1, 2]. Although previous literature has reported satisfactory long-term results of laminoplasty, most of these evaluations conducted in the past relied upon the physicians' point of view using the Japanese Orthopaedic Association (JOA) scoring system and image findings such as range of motion [3–6]. Based on the concept that ultimately the evaluation

Table 1 Characteristics of the study population

	$N = 97$
Age (year), mean (SD)	64.3 (10.6)
Gender	
Male	61
Female	36
Follow-up (m), mean (range)	58 (12–123)
Diagnosis (*N*)	
CSM	59
OPLL	36
OYL	1
CDH	1
Surgical levels (*N*)	
C3–7	62
C2–7	18
C3–6	6
Others	11

SD standard deviation, *CSM* cervical spondylotic myelopathy, *OPLL* ossification of the posterior longitudinal ligament, *OYL* ossification of the yellow ligament, *CDH* cervical disc hernia

of treatment results is best done by the patient, the use of several patient-reported outcomes (PROs), such as the visual analog scale, numerical rating scale (NRS), and Short-Form 36 (SF-36), after surgical intervention has become popular in the field of spine surgery [7–9].

A high level of patient satisfaction should be the most important goal following surgery. Although there have been many reports regarding the level of patient satisfaction following other surgeries [10–14], the level after cervical posterior laminoplasty remains to be established [15, 16]. In addition, PROs associated with patient satisfaction after surgical intervention for cervical compression myelopathy remain unclear.

This study aimed to investigate patient satisfaction with double-door laminoplasty for cervical compression myelopathy and to identify the PROs associated with postoperative patient satisfaction.

Materials and methods

Patient population

We reviewed 106 consecutive patients with cervical compression myelopathy who underwent double-door laminoplasty between 2002 and 2010 in our institution. Of these, four patients were lost to follow-up before evaluation of the postoperative outcome. Five patients developed complications, which included C5 motor palsy in four patients and concurrent reoperation for postoperative deterioration due to suboptimal decompression in one patient; these influenced patient satisfaction. The patients with complications were excluded from the study so as to evaluate the association between PROs and patient satisfaction in the population that had an uneventful postoperative course. Finally, 97 patients [mean follow-up 58 months (range 12–123 months)] were included. Of these, 59 had cervical spondylotic myelopathy, 36 had cervical ossification of the posterior longitudinal ligament, one had cervical ossification of the yellow ligament, and one had cervical disc hernia. The most common surgical levels were C3/C7 in 62 patients, followed by C2/C7 in 18 patients and C3/C6 in six patients (Table 1).

Informed consent was obtained from each patient, and the study was approved by the institutional review board of the University of Tokyo.

Double-door laminoplasty

We performed double-door laminoplasty as described in a previous report [6]. Cervical laminae were exposed laterally to the medial aspect of the facet joints, and the interspinous ligaments were removed. The spinous processes were split sagittally. After bilateral gutters for the hinges were carefully made at the transitional area between the facet joint and laminae, spinal canal enlargement was achieved by bilateral opening of the laminae. HA spacers (Boneceram; Olympus Terumo Biomaterials Corp., Tokyo, Japan) were placed between the opening laminae and fixed with nonabsorbable sutures. Patients wore a soft cervical orthosis for approximately 3 weeks.

Outcome measures and questionnaires

We assessed the preoperative outcome of patients from the questionnaires administered before surgery, during their hospital admission. Questionnaires included several PROs, as follows: the Neck Disability Index (NDI) [17], physical component summary (PCS) and mental component summary (MCS) of SF-36 [18], EuroQol-5 dimension, Japanese Orthopaedic Association Cervical Myelopathy Evaluation Questionnaire (JOACMEQ) [19], and NRS of pain or numbness in the neck, arms, and scapular lesion. Postoperatively, questionnaires that included the above-mentioned PROs in addition to the original satisfaction scales that assessed the postoperative outcome were sent to the patients. Satisfaction was evaluated based on a seven-point scale as follows: very satisfied, satisfied, slightly satisfied, neither satisfied nor dissatisfied, slightly dissatisfied, dissatisfied, and very dissatisfied. Patients were divided into two groups: satisfied (very satisfied, satisfied, slightly satisfied) and dissatisfied (neither satisfied nor dissatisfied, slightly dissatisfied, dissatisfied, very dissatisfied). The postoperative PROs were evaluated using questionnaires administered at the latest follow-up.

Assessment of the effectiveness of surgical intervention

Effectiveness of the treatment was assessed using the JOA scoring system administered by a physician and JOACMEQ.

The recovery rate of the JOA scoring system was calculated using Hirabayashi's method as follows [2]: Recovery rate (%) = (postoperative JOA score − preoperative JOA score) × 100/(17 − preoperative JOA score). Effectiveness of surgical treatment based on the JOA score was defined as a recovery rate ≥50 % [20].

According to a previous report [19], effectiveness of surgical treatment in each domain of the JOACMEQ was defined as follows: (1) the post-treatment score was higher than the pretreatment score by ≥20 points, and (2) the pretreatment score was <90 and the post-treatment score reached ≥90 points. Patients with preoperative and postoperative scores >90 were excluded from this analysis.

Statistical analysis

All PROs and the effectiveness of surgical treatment were compared between both groups. Continuous outcomes were compared using the one-factor analysis of variance, and categorical outcomes were compared using the Chi square test and Fisher's exact test. Multivariate logistic regression models were prepared to estimate patient satisfaction associated with potential predictors including demographic variables and postoperative PROs, which were significantly different between the two groups in univariate analysis. All statistical analyses were conducted using JMP Pro 10 (SAS Institute, Cary, NC). The threshold for significance was a *p* value <0.05.

Results

Table 2 demonstrates PROs compared between preoperative and postoperative assessments. NDI, PCS of SF-36, EQ-5D, arm pain, and arm numbness were improved between preoperative and postoperative assessment. The preoperative and postoperative differences in neck pain, scapular pain, neck numbness, and scapular numbness were not significant. The satisfied group comprised 69 patients (71 %) and the dissatisfied group comprised the remaining 28 patients (29 %). Table 3 demonstrates the pathology of cervical compression myelopathy (the presence or absence of OPLL), surgical level (including C2 or C7, or neither), and the preoperative PROs of the two groups. None of the preoperative PROs were significantly different between the two groups. There was no significant difference in the pathology of cervical compression myelopathy and surgical level between the two groups.

Table 2 Patient reported outcomes compared between preoperative and postoperative assessments [mean (SD)]

	Preoperative assessment	Postoperative assessment	*p* value
NDI	36.0 (20.7)	27.3 (16.1)	<0.0001
PCS	20.6 (18.6)	32.1 (18.6)	<0.0001
MCS	49.6 (10.6)	50.9 (9.5)	0.44
EQ-5D	0.55 (0.21)	0.70 (0.19)	<0.0001
NRS (pain)			
Neck	3.4 (3.2)	2.9 (2.6)	0.17
Arms	4.2 (3.2)	2.9 (2.7)	<0.01
Scapular lesion	2.0 (2.6)	2.2 (2.6)	0.19
NRS (numbness)			
Neck	2.2 (2.9)	1.9 (2.5)	0.20
Arms	5.2 (3.0)	4.0 (3.0)	<0.01
Scapular lesion	2.0 (2.4)	1.9 (2.5)	0.96

SD standard deviation, *NDI* Neck Disability Index, *PCS* physical component summary of Short-Form 36, *MCS* mental component summary of Short-Form 36, *EQ-5D* EuroQol 5 dimension, *NRS* numerical rating scale

Univariate analysis revealed that the postoperative scapular pain, NDI, PCS of SF-36, MCS of SF-36, and effectiveness of treatment in the lower extremity evaluated using the JOACMEQ were significantly different between the two groups (Table 4). Patients in the satisfied group showed a tendency toward a higher recovery rate of the JOA score, as evaluated by a physician, compared to the dissatisfied group; however, the difference was not significant. Table 5 demonstrates the results of multivariable logistic regression models for satisfaction with double-door laminoplasty. After adjusting for confounders, the effectiveness of treatment in the lower extremity, evaluated using the JOACMEQ, was significantly higher in the satisfied group than in the dissatisfied group (Odds ratio = 3.77; 95 % CI, 1.13–15.3; $p = 0.03$).

Discussion

This study had two main findings. First, 71 % of the patients who underwent double-door laminoplasty for cervical compression myelopathy were satisfied. Additionally, several PROs, including NDI, SF-36, NRS of pain in the scapular lesion, and effectiveness of treatment in the lower extremity, which was evaluated using the JOACMEQ, were associated with patient satisfaction. In particular,

Table 3 Pathology of cervical compression myelopathy, surgical level, and preoperative patient-reported outcomes compared between the two groups [mean (SD)]

	Satisfied group $N = 69$	Dissatisfied group $N = 28$	p value[a]
Pathology of myelopathy OPLL presence [N (%)]	27 (39)	9 (32)	0.52
Surgical level including C2 or C7 [N (%)]	63 (91)	28 (100)	0.18[b]
NDI	37.5 (20.8)	31.9 (20.1)	0.23
PCS	20.4 (19.1)	21.0 (17.7)	0.89
MCS	49.9 (10.9)	48.9 (9.9)	0.67
EQ-5D	0.54 (0.21)	0.58 (0.21)	0.45
NRS (pain)			
Neck	3.4 (3.3)	3.6 (3.1)	0.77
Arms	4.3 (3.1)	3.9 (3.6)	0.60
Scapular lesion	1.8 (2.5)	2.5 (2.7)	0.25
NRS (numbness)			
Neck	2.1 (2.9)	2.7 (2.9)	0.43
Arms	5.6 (2.9)	4.4 (3.0)	0.16
Scapular lesion	1.7 (2.3)	2.6 (2.6)	0.15

SD standard deviation, *OPLL* ossification of the posterior longitudinal ligament, *NDI* Neck Disability Index, *PCS* physical component summary of Short-Form 36, *MCS* mental component summary of Short-Form 36, *EQ-5D* EuroQol 5 dimension, *NRS* numerical rating scale

[a] For continuous outcomes, the comparisons were made by the one-factor analysis of variance. For categorical outcomes, the comparisons were made by the Chi square test

[b] Fisher's exact test

multivariate logistic regression analysis revealed that effectiveness of treatment in the lower extremity evaluated using the JOACMEQ was a significant independent factor associated with patient satisfaction.

Although several studies on postoperative satisfaction in patients with cervical compression myelopathy have been previously conducted, evidence of patient satisfaction with the posterior operative approach is limited. With regard to cervical myelopathy due to multilevel compression, Sampath et al. [21] reported a 75 % satisfaction rate after surgery in their prospective multicenter study. However, their study was limited by a small sample size of 20 patients who underwent surgical intervention, and also included several procedures, including decompression through a posterior approach, anterior cervical discectomy, and spinal fusion with or without internal fixation with instrumentation. Although Fujimori et al. [15] found that 80 % of patients with cervical myelopathy due to multilevel compression by OPLL were satisfied with the surgical results, this study also included both posterior and anterior procedures. The present study was superior compared to previous reports regarding patient satisfaction following posterior cervical surgery in that it used data from approximately 100 patients following double-door laminoplasty as a single procedure. Moreover, the satisfaction scale in this study was classified into seven categories, whereas previous classifications in other studies had only five categories. The detailed questionnaire in this study may reflect patient satisfaction with more accuracy.

This study found that several PROs, such as NDI, SF-36, scapular pain, and effectiveness of treatment in the lower extremity assessed using the JOACMEQ, were associated with patient satisfaction. In particular, the effect of surgical intervention on the lower extremity, which was evaluated using the JOACMEQ, was reflected in patient satisfaction with double-door laminoplasty independently. Fujimori et al. [15], in their study of 69 patients with cervical OPLL, found that lower extremity function correlated with patient satisfaction, which was similar to the findings of this study. With regard to the reason why lower extremity function was identified as an independent factor of satisfaction, we speculate the following possibilities. The patients who did not feel improvement in lower extremity function might be dissatisfied because lower extremity function reportedly correlates more directly with quality of life than upper extremity function [22]. Fujimori et al. [15] found that many patients who were dissatisfied reported inability to move around independently as the reason in their response to open-type questions. This study confirmed the postulate that lower extremity function correlated more strongly with patient satisfaction. Moreover, a previous study demonstrated that following surgery, neurological recovery in the lower extremity was less likely to achieve neurological improvement compared to the upper extremity [23, 24]; this may play a role in the dissatisfaction experienced by the patients. Furthermore, patients in the current study might have suffered from degenerative diseases that affect

Table 4 Postoperative outcomes compared between the two groups [mean (SD)]

	Satisfied group	Dissatisfied group	*p* value[a]
NDI	24.4 (15.8)	34.3 (14.8)	<0.01
PCS	34.8 (18.8)	25.6 (16.8)	0.03
MCS	52.2 (9.6)	47.7 (8.7)	0.04
EQ-5D	0.72 (0.21)	0.64 (0.14)	0.05
NRS (pain)			
Neck	2.6 (2.6)	3.6 (2.5)	0.12
Arms	2.6 (2.7)	3.5 (2.5)	0.14
Scapular lesion	1.8 (2.5)	3.2 (2.6)	0.01
NRS (numbness)			
Neck	1.7 (2.6)	2.3 (2.3)	0.29
Arms	3.9 (3.0)	4.4 (3.0)	0.46
Scapular lesion	1.6 (2.5)	2.5 (2.6)	0.12
JOA score recovery rate	46.8 % (41.5)	32.1 % (31.4)	0.10
Effectiveness of surgical treatment evaluated using JOACMEQ [*N* (%)]			
Cervical spine function	20 (34)	7 (29)	0.80
Upper extremity function	27 (44)	7 (28)	0.23
Lower extremity function	30 (49)	4 (16)	<0.01
Bladder function	15 (26)	2 (8)	0.08
Quality of life	14 (23)	4 (16)	0.57

SD standard deviation, *NDI* Neck Disability Index, *PCS* physical component summary of Short-Form 36, *MCS* mental component summary of Short-Form 36, *EQ-5D* EuroQol 5 dimension, *NRS* numerical rating scale, *JOA* Japanese Orthopaedic Association, *JOACMEQ* Japanese Orthopaedic Association Cervical Myelopathy Evaluation Questionnaire

[a] For continuous outcomes, comparisons were made by the one-factor analysis of variance. For categorical outcomes, the comparisons were made by the Fisher's exact test

Table 5 Multivariable logistic regression models for patient satisfaction after double-door laminoplasty

	Patient satisfaction		
	OR	95 % CI	*p* value
Age	0.99	0.93–1.05	0.64
Female (ref. male)	0.99	0.30–3.47	0.99
Postoperative NDI	1.01	0.96–1.07	0.69
Postoperative PCS	0.99	0.94–1.03	0.55
Postoperative MCS	0.94	0.87–1.02	0.13
Postoperative scapular pain	1.05	0.83–1.34	0.65
Effective in LE (ref. non-effective)	3.77	1.13–15.3	0.03

OR odds ratio, *CI* confidence interval, *NDI* Neck Disability Index, *PCS* physical component summary of Short-Form 36, *MCS* mental component summary of Short-Form 36

lower extremity function (e.g., knee osteoarthritis or lumbar spinal stenosis). Prior study revealed a high prevalence of knee osteoarthritis and lumbar spinal stenosis in the Japanese elderly [25, 26], which may be one of the reasons for insufficient improvement in lower extremity function compared to that in upper extremity function.

Although several factors have been reported to affect the outcome following laminoplasty, so far, the predictor for optimal timing of laminoplasty remains unknown. Age, preoperative JOA, signal intensity change on MRI, and cervical lordotic angle were reportedly associated with postoperative outcome in a previous study [27–30]. However, the prognostic significance of these factors has not been established. Timing of surgical intervention should be decided according to the expected postoperative satisfaction in addition to neurological improvement. This study found that the improvement of lower extremity function following surgical intervention was as an independent factor associated with patient satisfaction, which suggests that the factors reflecting severity of myelopathy in the lower extremity is important. Two clinical tests were reported for evaluation of lower extremity function in patients with cervical myelopathy. Mihara et al. [31] demonstrated that the triangle step test was a very useful method for evaluation of lower extremity function in patients with cervical myelopathy. Nakashima et al. [20] reported the 10-s step test as a simple physical assessment for severity of cervical compression myelopathy, particularly for lower extremity dysfunction. These tests can be candidate predictors for patient satisfaction following laminoplasty. Further research regarding predictors reflecting satisfaction to decide optimal timing of surgical intervention is expected in the future.

According to previous studies, satisfaction in patients with cervical myelopathy following anterior approach procedures ranges from 80.6 to 94.7 % [11, 13]. In the current study, postoperative patient satisfaction following posterior approach procedures was 71 %, and including the five patients with complications (one patient in the satisfied group and four patients in the dissatisfied group) in the analysis, it was 69 %. Despite recognition of posterior laminoplasty as an established treatment for cervical compression myelopathy, our data revealed that patient satisfaction following double-door laminoplasty was relatively low compared to that following the anterior approach. One of the reasons for this might be that patients undergoing laminoplasty often complain of axial pain, which may play a role in decreasing the level of patient satisfaction. Indeed, the satisfied group had a significantly lower postoperative numerical scapular pain scale in this study. Several factors, including different surgical techniques, radiological assessment, and postoperative management, were reportedly associated with axial pain following posterior cervical surgery [32]. Further surgical modification, such as less invasive surgery and postoperative management including medication and early removal of cervical orthosis, should be attempted for improvement of postoperative scapular pain.

This study had several limitations. First, the surgery was not performed by the same surgeon in all patients, nor was it performed to the same surgical level. Surgical invasion may vary slightly between surgeons and surgical level. The inconsistency of surgical techniques performed can affect postoperative outcome. Indeed, such surgical factors were reported to be associated with axial pain after posterior cervical spine surgery [32, 33]. However, the preservation of muscles attached at C2 or C7 was not associated with patient satisfaction in this study. Second, the questionnaire used in this study did not assess the outcomes immediately after the surgical procedure. In particular, perioperative pain immediately after surgical procedure may cause decreased satisfaction. Further study with perioperative evaluation that includes use of a numerical pain scale and medication and cervical immobilization is required to verify the influence of perioperative management on patient satisfaction. Third, although we examined the patients with cervical compression myelopathy, including those with and without OPLL, the difference in the pathomechanism of myelopathy between those with OPLL and others may have affected the surgical outcome. Although there was no significant difference in the pathology of cervical compression myelopathy between the satisfied and dissatisfied groups, further large-scale studies that take these differences in the pathology into consideration are warranted. Finally, the relationship between the physician and the patient was not evaluated in this study. There may be bias related to this factor. We used a questionnaire for evaluation of satisfaction instead of directing the questions to the physician to decrease this bias. Despite these limitations, we believe that this study has valuable information that is of clinical importance.

In conclusion, 71 % of the patients who underwent double-door laminoplasty for cervical compressive myelopathy were satisfied. The findings in this study suggest that improvement in lower extremity function following surgical intervention affects patient satisfaction.

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Kurokawa T. Double-door laminoplasty by longitudinal splitting of the spinal processes. Bessatsu Seikeigeka. 1982;2:234–40 (in Japanese).
2. Hirabayashi K, Miyakawa J, Satomi K, Maruyama T, Wakano K. Operative results and postoperative progression of ossification among patients with ossification of cervical posterior longitudinal ligament. Spine (Phila Pa 1976). 1981;6(4):354–64.
3. Chiba K, Ogawa Y, Ishii K, Takaishi H, Nakamura M, Maruiwa H, Matsumoto M, Toyama Y. Long-term results of expansive open-door laminoplasty for cervical myelopathy average 14-year follow–up study. Spine (Phila Pa 1976). 2006;31(26):2998–3005.
4. Iwasaki M, Kawaguchi Y, Kimura T, Yonenobu K. Long-term results of expansive laminoplasty for ossification of the posterior longitudinal ligament of the cervical spine: more than 10 years follow up. J Neurosurg. 2002;96(2 Suppl):180–9.
5. Kimura A, Seichi A, Inoue H, Hoshino Y. Long-term results of double-door laminoplasty using hydroxyapatite spacers in patients with compressive cervical myelopathy. Eur Spine J. 2011;20(9):1560–6.
6. Seichi A, Takeshita K, Ohishi I, Kawaguchi H, Akune T, Anamizu Y, Kitagawa T, Nakamura K. Long-term results of double-door laminoplasty for cervical stenotic myelopathy. Spine (Phila Pa 1976). 2001;26(5):479–87.
7. Copay AG, Martin MM, Subach BR, Carreon LY, Glassman SD, Schuler TC, Berven S. Assessment of spine surgery outcomes: inconsistency of change amongst outcome measurements. Spine J. 2010;10(4):291–6.
8. DeVine J, Norvell DC, Ecker E, Fourney DR, Vaccaro A, Wang J, Andersson G. Evaluating the correlation and responsiveness of patient-reported pain with function and quality-of-life outcomes after spine surgery. Spine (Phila Pa 1976). 2011;36(21 Suppl):S69–74.
9. McCormick JD, Werner BC, Shimer AL. Patient-reported outcome measures in spine surgery. J Am Acad Orthop Surg. 2013;21(2):99–107.
10. Baker PN, van der Meulen JH, Lewsey J, Gregg PJ. National joint registry for England and Wales. The role of pain and function in determining patient satisfaction after total knee replacement. Data from the National joint registry for England and Wales. J Bone Joint Surg Br. 2007;899(7):893–900.
11. Chagas H, Domingues F, Aversa A, Vidal Fonseca AL, de Souza JM. Cervical spondylotic myelopathy: 10 years of prospective outcome analysis of anterior decompression and fusion. Surg Neurol. 2005;64 Suppl 1(S1):30–5.
12. Gepstein R, Arinzon Z, Adunsky A, Folman Y. Decompression surgery for lumbar spinal stenosis in the elderly: preoperative expectations and postoperative satisfaction. Spinal Cord. 2006;44(7):427–31.
13. Riew KD, Buchowski JM, Sasso R, Zdeblick T, Metcalf NH, Anderson PA. Cervical disc arthroplasty compared with arthrodesis for the treatment of myelopathy. J Bone Joint Surg Am. 2008;90(11):2354–64.
14. Toyone T, Tanaka T, Kato D, Kaneyama R, Otsuka M. Patients' expectations and satisfaction in lumbar spine surgery. Spine (Phila Pa 1976). 2005;30(23):2689–94.
15. Fujimori T, Iwasaki M, Okuda S, Nagamoto Y, Sakaura H, Oda T, Yoshikawa H. Patient satisfaction with surgery for cervical myelopathy due to ossification of the posterior longitudinal ligament. J Neurosurg Spine. 2011;14(6):726–33.
16. Neo M, Fujibayashi S, Takemoto M, Nakamura T. Clinical results of and patient satisfaction with cervical laminoplasty for considerable cord compression with only slight myelopathy. Eur Spine J. 2012;21(2):340–6.
17. Vernon H, Mior S. The Neck disability index: a study of reliability and validity. J Manipulative Physiol Ther. 1991;14(7):409–15.
18. Ware JE Jr, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. Med Care. 1992;30(6):473–83.

19. Fukui M, Chiba K, Kawakami M, Kikuchi S, Konno S, Miyamoto M, Seichi A, Shimamura T, Shirado O, Taguchi T, Takahashi K, Takeshita K, Tani T, Toyama Y, Yonenobu K, Wada E, Tanaka T, Hirota Y. Subcommittee of the clinical outcome committee of the Japanese Orthopaedic Association on low back pain and cervical myelopathy evaluation. JOA Back Pain Evaluation Questionnaire (JOABPEQ)/JOA Cervical Myelopathy Evaluation Questionnaire (JOACMEQ). The report on the development of revised versions. April 16, 2007. The subcommittee of the clinical outcome committee of the Japanese Orthopaedic Association on low back pain and cervical myelopathy evaluation. J Orthop Sci. 2009;14(3):348–65.
20. Nakashima H, Yukawa Y, Ito K, Machino M, Kanbara S, Morita D, Takahashi H, Imagama S, Ito Z, Ishiguro N, Kato F. Prediction of lower limb functional recovery after laminoplasty for cervical myelopathy: focusing on the 10-s step test. Eur Spine J. 2012;21:1389–95.
21. Sampath P, Bendebba M, Davis JD, Ducker TB. Outcome of patients treated for cervical myelopathy. A prospective, multicenter study with independent clinical review. Spine (Phila Pa 1976). 2000;25(6):670–6.
22. King JT Jr, McGinnis KA, Roberts MS. Quality of life assessment with the medical outcomes study short form-36 among patients with cervical spondylotic myelopathy. Neurosurgery. 2003;52(1):113–20.
23. Cheung WY, Arvinte D, Wong YW, Luk KD, Cheung KM. Neurological recovery after surgical decompression in patients with cervical spondylotic myelopathy—a prospective study. Int Orthop. 2008;32(2):273–8.
24. Chiles BW 3rd, Leonard MA, Choudhri HF, Cooper PR. Cervical spondylotic myelopathy: patterns of neurological deficit and recovery after anterior cervical decompression. Neurosurgery. 1999;44(4):762–9.
25. Muraki S, Oka H, Akune T, Mabuchi A, En-yo Y, Yoshida M, Saika A, Suzuki T, Yoshida H, Ishibashi H, Yamamoto S, Nakamura K, Kawaguchi H, Yoshimura N. Prevalence of radiographic knee osteoarthritis and its association with knee pain in the elderly of Japanese population-based cohorts: the ROAD study. Osteoarthritis Cartilage. 2009;17(9):1137–43.
26. Ishimoto Y, Yoshimura N, Muraki S, Yamada H, Nagata K, Hashizume H, Takiguchi N, Minamide A, Oka H, Kawaguchi H, Nakamura K, Akune T, Yoshida M. Prevalence of symptomatic lumbar spinal stenosis and its association with physical performance in a population-based cohort in Japan: the Wakayama spine study. Osteoarthritis Cartilage. 2012;20(10):1103–8.
27. Kohno K, Kumon Y, Oka Y, Matsui S, Ohue S, Sakaki S. Evaluation of prognostic factors following expansive laminoplasty for cervical spinal stenotic myelopathy. Surg Neurol. 1997;48(3):237–45.
28. Tanaka J, Seki N, Tokimura F, Doi K, Inoue S. Operative results of canal-expansive laminoplasty for cervical spondylotic myelopathy in elderly patients. Spine (Phila Pa 1976). 1999;24(22):2308–12.
29. Suda K, Abumi K, Ito M, Shono Y, Kaneda K, Fujiya M. Local kyphosis reduces surgical outcomes of expansive open door laminoplasty for cervical spondylotic myelopathy. Spine (Phila Pa 1976). 2003;28(12):1258–62.
30. Yukawa Y, Kato F, Yoshihara H, Yanase M, Ito K. MR T2 image classification in cervical compression myelopathy: predictor of surgical outcomes. Spine (Phila Pa 1976). 2007;32(15):1675–8.
31. Mihara H, Kondo S, Murata A, Ishida K, Niimura T, Hachiya M. A new performance test for cervical myelopathy: the triangle step test. Spine (Phila Pa 1976). 2010;35(1):32–5.
32. Wang SJ, Jiang SD, Jiang LS, Dai LY. Axial pain after posterior cervical spine surgery: a systematic review. Eur Spine J. 2011;20(2):185–94.
33. Kato M, Nakamura H, Konishi S, Dohzono S, Toyoda H, ima W, Kondo K, Matsuda H. Effect of preserving paraspinal muscles on postoperative axial pain in the selective cervical laminoplasty. Spine (Phila Pa 1976). 2008;33(14):E455–9.

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Joint space narrowing, body mass index, and knee pain: the ROAD study (OAC1839R1)

S. Muraki † *, T. Akune †, Y. En-yo ‡, M. Yoshida ‡, T. Suzuki §, H. Yoshida ||, H. Ishibashi ¶, F. Tokimura #, S. Yamamoto ††, S. Tanaka ‡‡, K. Nakamura §§, H. Kawaguchi ||||, H. Oka ¶¶, N. Yoshimura ¶¶

† Department of Clinical Motor System Medicine, 22nd Century Medical & Research Center, Faculty of Medicine, the University of Tokyo, Tokyo, Japan
‡ Department of Orthopaedic Surgery, Wakayama Medical University, Wakayama, Japan
§ National Center for Geriatrics and Gerontology, Aichi, Japan
|| Research Team for Promoting Independence of the Elderly, Tokyo Metropolitan Institute of Gerontology, Tokyo, Japan
¶ Department of Orthopaedic Surgery, Ina Hospital, Saitama, Japan
# Department of Orthopaedic Surgery, Tokyo Geriatric Medical Center, Tokyo, Japan
†† Department of Orthopaedic Surgery, Toranomon Hospital, Tokyo, Japan
‡‡ Department of Orthopaedic Surgery, Faculty of Medicine, the University of Tokyo, Tokyo, Japan
§§ National Rehabilitation Center for Persons with Disabilities, Saitama, Japan
|||| Department of Orthopaedic Surgery, Japan Community Health Care Organization Tokyo Shinjuku Medical Center, Tokyo, Japan
¶¶ Department of Joint Disease Research, 22nd Century Medical & Research Center, Faculty of Medicine, The University of Tokyo, Tokyo, Japan

A R T I C L E I N F O

Article history:
Received 16 July 2014
Accepted 20 January 2015

Keywords:
Cohort study
Epidemiology
Osteoarthritis
Pain

S U M M A R Y

Objective: The objective of the present study was to clarify the association of joint space narrowing with knee pain in Japanese men and women using a large-scale population-based cohort of the Research on Osteoarthritis/osteoporosis Against Disability (ROAD) study.

Methods: This study examined the association between minimum joint space width (mJSW) in the medial compartment and pain at the knee. mJSW was measured in the medial and lateral compartments of the knee using a knee osteoarthritis (OA) computer-aided diagnosis system.

Results: From the 3040 participants in the ROAD study, the present study analyzed 2733 participants who completed the radiographic examinations and questionnaires regarding knee pain (975 men and 1758 women; mean age, 69.9 ± 11.2 years). Subjects with lateral knee OA were excluded. After adjustment for age and Body mass index (BMI), medial mJSW, as well as medial mJSW/lateral mJSW, was significantly associated with knee pain. Sex and BMI affected the association of medial mJSW with knee pain. The threshold of medial mJSW was approximately 3 mm in men and 2 mm in women, while that of medial mJSW/lateral mJSW was approximately 60% in both men and women. BMI was found to have a distinct effect on the association of mJSW with pain.

Conclusion: The present cross-sectional study using a large-scale population from the ROAD study showed that joint space narrowing had a significant association with knee pain. The thresholds of joint space narrowing for knee pain were also established.

Introduction

Knee osteoarthritis (OA) is a major public health issue that causes chronic pain and disability[1–3]. The prevalence of radiographic knee OA is high in Japan [4], with 25,300,000 persons aged 40 years and older estimated to have radiographic knee OA[5]. According to the recent National Livelihood Survey of the Ministry of Health, Labour and Welfare in Japan, OA is ranked fourth among diseases that cause disabilities that subsequently require support with activities of daily living[6].

* Address correspondence and reprint requests to: S. Muraki, Department of Clinical Motor System Medicine, 22nd Century Medical and Research Center, Faculty of Medicine, The University of Tokyo, Hongo 7-3-1, Bunkyo-ku, Tokyo 113-8655, Japan. Tel: 81-3-5800-9178; Fax: 81-3-5800-9179.
E-mail address: murakis-ort@h.u-tokyo.ac.jp (S. Muraki).

http://dx.doi.org/10.1016/j.joca.2015.01.011
1063-4584/

Please cite this article in press as: Muraki S, et al., Joint space narrowing, body mass index, and knee pain: the ROAD study (OAC1839R1), Osteoarthritis and Cartilage (2015), http://dx.doi.org/10.1016/j.joca.2015.01.011

Knee pain is the principal clinical symptom of knee OA[7]. Although much effort has been devoted toward a definition of knee pain, the correlation with radiographic severity of the knee OA was not as strong as one would expect[4,8–10]. One of the reasons for this apparent discrepancy may be the definition of knee OA. Kellgren Lawrence (KL) grading is the conventional system most used to grade the radiographic severity of knee OA[11], but in this categorical system, joint space narrowing is not assessed separately. A recent cross-sectional study showed that the association between joint space narrowing and osteophytosis was not as high as expected on plain radiographs[12]. In addition, joint space narrowing and osteophytosis had distinct effects on QOL[12]. These accumulating lines of evidence have indicated that joint space narrowing and osteophytosis may have distinct etiologic mechanisms, and their progression may be neither constant nor proportional. Although osteophytosis also has some effect on ADL and QOL[12], joint space narrowing is the primary outcome in studies of OA[13]. Thus, to examine the association between knee OA and pain, joint space narrowing should be assessed separately. Chan *et al.* examined the association of joint space narrowing and duration of pain in patients with knee OA and found a significant association[14], but joint space narrowing was defined by categorical methods. Because categorical methods are statistically less powerful than continuous methods, the association between pain and knee OA might have been underestimated. To overcome this, a fully automatic system that can quantify the joint space width of knee OA on standard radiographs and allows for objective, accurate, and simple assessment of the structural severity of knee OA was developed[15]. Thus far, Kinds *et al.* measured joint space width and found significant associations with clinical outcomes[16], but the threshold of joint space width for clinical outcomes remains unclear.

Sex differences have been observed in knee OA. The prevalence of knee OA is higher in women than men, and the association of knee pain with knee OA also differs by sex[4]. Thus, the impact of joint space narrowing and osteophytosis on QOL may also differ between the sexes. Obesity is also one of the few established risk factors for knee OA and pain[17–23]. This suggests that a distinct association of joint space narrowing with pain may be found in subjects with and without obesity. However, to the best of our knowledge, there are no population-based studies that assess the effect of obesity on the association of joint space narrowing with pain.

Therefore, the objective of this study was to clarify the association of joint space narrowing with pain at the knee among Japanese men and women using a fully automatic system to measure joint space width in a large-scale, population-based cohort from the Research on Osteoarthritis/osteoporosis Against Disability (ROAD) study. Furthermore, the threshold of minimum joint space width (mJSW) or medial mJSW/lateral mJSW for pain was determined using receiver operating characteristic (ROC) curve analysis.

Subjects and methods

Subjects

The ROAD study is a nationwide prospective study designed to establish epidemiologic indices for the evaluation of clinical evidence for the development of a disease-modifying treatment for bone and joint diseases (with OA and osteoporosis as the representative bone and joint diseases). It consists of population-based cohorts in several communities in Japan. A detailed profile of the ROAD study has been reported elsewhere[4,5,24], and, thus, only a brief summary is provided here. To date, we have completed the creation of a baseline database including clinical and genetic information for 3040 inhabitants (1061 men and 1,979 women) ranging in age from 23 to 95 years (mean, 70.3 years), who were recruited from resident registration listings in three communities: an urban region in Itabashi, Tokyo, a mountainous region in Hidakagawa, Wakayama, and a coastal region in Taiji, Wakayama. All participants provided their written, informed consent, and the study was conducted with the approval of the ethics committees of the University of Tokyo and the Tokyo Metropolitan Institute of Gerontology. Anthropometric measurements, including height and weight, were taken, and body mass index (BMI; weight [kg]/height^2 [m^2]) was calculated. Furthermore, all participants were also interviewed by well-experienced orthopedists regarding pain in both knees, by asking: “Have you experienced right knee pain on most days in the past month, in addition to now?” and “Have you experienced left knee pain on most days in the past month, in addition to now?”. Subjects who answered “yes” were defined as having knee pain. Among the 3040 subjects who participated in the baseline study, 30 (1.0%) who underwent unilateral or total knee arthroplasty were excluded. In addition, 35 (1.1%) whose radiographic examinations were insufficient for measuring joint space width, and 195 (6.4%) with lateral knee OA were excluded. One reason for excluding lateral knee OA is that most knee OA in Japan is medial type[4]. The other reason is that medial and lateral knee OA have distinct characteristics, and joint space narrowing occurs in the medial compartment in medial knee OA, but medial joint space width may not change or be larger in lateral knee OA. Furthermore, 47 patients (1.5%) who provided incomplete questionnaires regarding pain and so on were excluded, leaving a total of 2733 (89.9%) subjects (975 men and 1758 women).

Radiographic assessment

All participants underwent radiographic examinations of both knees using an anterior-posterior view with weight-bearing and foot map positioning by experienced radiological technologists. The beam was positioned parallel to the floor with no angle and aimed at the joint space. To visualize the joint space properly and to centralize the patella over the lower end of the femur, fluoroscopic guidance with an anterior-posterior X-ray beam was used, and the images were downloaded into Digital Imaging and Communication in Medicine (DICOM) format files. Knee radiographs were read without knowledge of participant clinical status by a single experienced orthopedist (S.M.) using the KL radiographic atlas for overall knee radiographic grades[11], and knee OA was defined as KL grade 2 or greater. The KOACAD system was used to measure mJSW in the medial compartment and OPA at the medial tibia[15], and the knee with the lower mJSW was defined as the designated knee for a participant. The KOACAD system is a fully automatic system that can quantify the major features of knee OA on standard radiographs and allows for objective, accurate, and simple assessment of the structural severity of knee OA in general clinical practice. This system was programmed to measure mJSW in the medial and lateral compartments using digitized knee radiographs. The KOACAD system has been described in detail elsewhere[15,25]. The KOACAD system was applied to the DICOM data by the experienced orthopedist who developed this system (H.O.); measurement reliability has been shown to be good[15], and the intraclass coefficient of correlation for medial mJSW measured on radiographs for an individual with weight-bearing and foot map positioning was 0.96. Reference values for OPA and mJSW by sex and age strata in Japan using the KOACAD system have been published previously[25]. Lateral knee OA was defined as KL grade 2 or greater with lower lateral mJSW than medial mJSW.

Statistical analysis

Differences in age, height, weight, BMI, mJSW, and medial/lateral mJSW between men and women and between subjects with and

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without pain were examined by the non-paired Student's *t*-test. The prevalence of knee OA was compared between men and women by the χ^2 test. Associations of age, BMI, mJSW, and medial/lateral mJSW with knee pain were determined using multiple logistic regression analysis after adjustment for age, sex, and BMI overall, and after adjustment for age and BMI in men and women. In addition, subjects were classified according to mJSW (<1 mm, ≥1–<2 mm, ≥2–<3 mm, ≥3–<4 mm, ≥4 mm), and the associations of mJSW<1 mm, ≥1–<2 mm, ≥2–<3 mm, and ≥3–<4 mm with pain were determined using multiple logistic regression analysis after adjustment for age and BMI, compared with mJSW≥4 mm. To clarify the effect of BMI on the association of mJSW with pain, subjects were further classified into 10 groups according to mJSW and BMI (BMI <23 kg/m^2: mJSW<1 mm, ≥1–<2 mm, ≥2–<3 mm, ≥3–<4 mm, ≥4 mm; BMI ≥ 23 kg/m^2: mJSW<1 mm, ≥1–<2 mm, ≥2–<3 mm, ≥3–<4 mm, ≥4 mm), and the association with pain was determined using multiple logistic regression analysis after adjustment for age, compared with BMI <23 kg/m^2 and mJSW ≥4 mm. Subjects were also classified according to medial/lateral mJSW (<30%, ≥30–<40%, ≥40–<50%, ≥50–<60%, ≥60–<70%, ≥70–<80%, ≥80%), and the associations of medial/lateral mJSW<30%, ≥30–<40%, ≥40–<50%, ≥50–<60%, ≥60–<70%, and ≥70–<80% with pain were determined using multiple logistic regression analysis after adjustment for age and BMI, compared with medial/lateral mJSW ≥80%. The thresholds of mJSW and medial/lateral mJSW for pain were determined using ROC curve analysis. Data analyses were performed using SAS version 9.0 (SAS Institute Inc., Cary, NC).

Results

The characteristics of the 2733 participants in the present study are shown in Table I. The prevalence of knee OA was significantly higher in women than in men. The mJSW and medial mJSW/lateral mJSW were significantly lower in women than in men. The participants in the present study were significantly younger than the non-participants ($P < 0.05$), while BMI was not significantly different between them (non-participants: age, 74.3 ± 7.9 years; BMI, 23.1 ± 3.2 kg/m^2).

Table II shows age, BMI, mJSW, and medial/lateral mJSW in subjects with and without pain. For the right knee, overall and in women, subjects with pain were older and had higher BMI, narrower mJSW, and smaller medial/lateral mJSW than those without pain. In men, subjects with pain had higher BMI, narrower mJSW, and smaller medial/lateral mJSW than subjects without pain, while age was not significantly different in men with and without pain. For the left knee, results were similar except for age in men. Associations of mJSW and medial/lateral mJSW with right and left knee pain were next examined using multiple logistic regression analysis after adjustment for age, sex, and BMI overall, and after adjustment for age and BMI in men and women (Table II). Odds ratios (ORs) of mJSW (1-mm decrease) for pain were higher than 2, and the ORs of medial/lateral mJSW (10% decrease) for pain were 1.2–1.3.

Subjects were then classified according to mJSW (<1 mm, ≥1–<2 mm, ≥2–<3 mm, ≥3–<4 mm, ≥4 mm), and the prevalence of knee pain was examined (Fig. 1, Supplementary Table I). The prevalence of knee pain was more than 60% in subjects with mJSW<1 mm, while it was less than 10% in those with mJSW ≥4 mm. The OR for pain was also calculated after adjustment for age and BMI. Men with mJSW <1 mm, ≥1–<2 mm, and ≥2–<3 mm had significantly higher rates of pain than those with mJSW ≥4 mm, but men with mJSW ≥3–<4 mm did not (Table III). The OR for pain in men with mJSW <1 mm was around 40. Women with mJSW <1 mm and ≥1–<2 mm had significantly higher rates of pain than those with mJSW ≥4 mm, but, women with mJSW ≥2–<3 mm and ≥3–<4 mm did not. The ORs for pain in women with mJSW <1 mm were 12–14. Subjects were further classified into 10 groups according to BMI and mJSW (BMI < 23 kg/m^2: mJSW < 1 mm, ≥1–<2 mm, ≥2–<3 mm, ≥3–<4 mm, ≥4 mm; BMI ≥ 23 kg/m^2: mJSW < 1 mm, ≥1–<2 mm, ≥2–<3 mm, ≥3–<4 mm, ≥4 mm), and the ORs for pain were calculated (Supplementary Table II). In men, mJSW<1 mm and ≥1–<2 mm with BMI <23 kg/m^2 and mJSW < 1 mm, ≥1–<2 mm, and ≥2–<3 mm with BMI ≥23 kg/m^2 were significantly associated with pain compared with mJSW ≥4 mm with BMI <23 kg/m^2. In women at the right knee, mJSW < 1 mm with BMI <23 kg/m^2 and mJSW ≥0–<1 mm and ≥1–<2 mm with BMI ≥23 kg/m^2 were significantly associated with pain compared with mJSW ≥4 mm with BMI <23 kg/m^2. In women at the left knee, mJSW < 1 mm and ≥1–<2 mm with BMI <23 kg/m^2 and mJSW < 1 mm, ≥1–<2 mm, and ≥2–<3 mm with BMI ≥23 kg/m^2 were significantly associated with pain compared with mJSW ≥4 mm with BMI <23 kg/m^2.

Subjects were also classified according to medial/lateral mJSW (<30%, ≥30–<40%, ≥40–<50%, ≥50–<60%, ≥60–<70%, ≥70–<80%, ≥80%), and the prevalence of knee pain was examined (Fig. 2, Supplementary Table III). The prevalence of knee pain was approximately 60% in subjects with medial mJSW/lateral mJSW < 30%, while it was approximately 10% in those with medial mJSW/lateral mJSW ≥80%. The ORs for pain were also calculated after adjustment for age and BMI (Table IV). Men and women with mJSW <30%, ≥30–<40%, ≥40–<50%, and ≥50–<60% had higher rates of pain compared with those with mJSW ≥80%, except for men with mJSW≥50–<60% at the right knee. The ORs for pain in men with mJSW <30% were 14–20. The OR for pain in women with mJSW <30% was around 10.

The threshold values of mJSW for knee pain were then determined using ROC curve analysis (Supplementary Fig. 1). In men, the threshold values of mJSW for pain at the right and left knees were 2.87 mm (sensitivity 0.67, specificity 0.65, AUC 0.70, 95% confidence interval (CI) 0.64–0.75) and 2.82 mm (sensitivity 0.62, specificity 0.67, AUC 0.72, 95% CI 0.66–0.77), respectively. In women, the threshold values of mJSW for pain at the right and left knees were 2.01 mm (sensitivity 0.43, specificity 0.689, AUC 0.69, 95% CI 0.66–0.73) and 2.44 mm (sensitivity 0.59, specificity 0.75, AUC 0.71, 95% CI 0.67–0.74), respectively. Threshold values of medial/lateral mJSW for knee pain were also determined using ROC curve analysis (Supplementary Fig. 2). In men, the threshold values of medial/lateral mJSW for pain at the right and left knees were 55.2% (sensitivity 0.45, specificity 0.68, AUC 0.66, 95% CI 0.60–0.72) and

Table I
Characteristics of the subjects in the present study

	Overall	Men	Women	*P* values
N	2733	975	1758	
Age, years	69.9 ± 11.2	70.8 ± 10.8	69.4 ± 11.4	0.0012
Height, cm	154.4 ± 8.9	162.5 ± 6.7	150.0 ± 6.4	<0.0001
Weight, kg	55.1 ± 10.3	61.4 ± 10.0	51.6 ± 8.7	<0.0001
BMI, kg/m^2	23.0 ± 3.3	23.2 ± 3.0	22.9 ± 3.5	0.0493
Right knee				
Knee OA, %	45.3	33.6	51.8	<0.0001
mJSW, mm	2.8 ± 1.0	3.2 ± 0.9	2.6 ± 0.9	<0.0001
medial mJSW/lateral mJSW, %	68.7 ± 30.1	71.1 ± 22.2	67.4 ± 33.6	0.0007
Left knee				
Knee OA, %	47.5	35.8	54	<0.0001
mJSW, mm	2.9 ± 1.0	3.3 ± 01.0	2.7 ± 0.9	<0.0001
medial mJSW/lateral mJSW, %	70.8 ± 26.3	73.9 ± 22.7	69.1 ± 28.0	<0.0001

Except where indicated otherwise, values are means ± SD.
Knee OA was defined as Kellgren Lawrence grade 2 or worse.
BMI, body mass index; OA, osteoarthritis; mJSW, minimum joint space width.

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Table II
Associations of age, BMI, mJSW, and medial mJSW/lateral mJSW with knee pain

	Right knee					Left knee				
	Pain +	Pain −	Adjusted OR	95% CI	*P* values	Pain +	Pain −	Adjusted OR	95% CI	*P* values
Overall										
N										
Age, years	72.4 ± 8.6	69.3 ± 11.6*	1.01	1.00–1.03	0.0499	72.8 ± 8.4	69.3 ± 11.6*	1.01	0.99–1.02	0.3226
BMI, kg/m^2	24.4 ± 3.6	22.7 ± 3.2*	1.12	1.08–1.16	<0.0001	24.2 ± 3.5	22.8 ± 3.2*	1.10	1.06–1.14	<0.0001
mJSW, mm (1-mm decrease)	2.1 ± 1.1	2.9 ± 0.9*	2.17	1.92–2.50	<0.0001	2.2 ± 1.1	2.9 ± 0.9*	2.22	1.96–2.56	<0.0001
medial mJSW/lateral mJSW, % (10% decrease)	54.3 ± 30.7	71.9 ± 29.0*	1.30	1.24–1.37	<0.0001	56.6 ± 30.4	71.0 ± 29.5*	1.22	1.16–1.29	<0.0001
Men										
N										
Age, years	71.7 ± 9.4	70.7 ± 11.0	0.99	0.96–1.02	0.5095	72.8 ± 8.7	70.5 ± 11.0*	0.98	0.95–1.01	0.2278
BMI, kg/m^2	24.2 ± 3.0	23.0 ± 3.0*	1.09	1.01–1.18	0.0207	24.1 ± 3.1	23.0 ± 3.0*	1.08	0.995–1.17	0.0635
mJSW, mm (1-mm decrease)	2.4 ± 1.2	3.3 ± 0.9*	2.33	1.82–3.03	<0.0001	2.6 ± 1.1	3.2 ± 0.9*	2.50	1.92–3.23	<0.0001
medial mJSW/lateral mJSW, % (10% decrease)	57.2 ± 27.6	72.8 ± 20.8*	1.33	1.19–1.49	<0.0001	61.3 ± 29.6	72.3 ± 20.8*	1.28	1.15–1.43	<0.0001
Women										
N										
Age, years	72.6 ± 8.4	68.5 ± 12.0*	1.02	1.005–1.04	0.0138	72.7 ± 8.3	68.6 ± 11.9*	1.02	0.997–1.04	0.0964
BMI, kg/m^2	24.4 ± 3.7	22.5 ± 3.3*	1.12	1.08–1.17	<0.0001	24.3 ± 3.6	22.6 ± 3.4*	1.11	1.06–1.16	<0.0001
mJSW, mm (1-mm decrease)	2.0 ± 1.1	2.8 ± 0.8*	2.13	1.82–2.50	<0.0001	2.1 ± 1.1	2.7 ± 0.8*	2.17	1.85–2.56	<0.0001
medial mJSW/lateral mJSW, % (10% decrease)	52.2 ± 31.5	71.4 ± 33.0*	1.30	1.22–1.38	<0.0001	55.1 ± 30.6	70.3 ± 33.7*	1.21	1.14–1.28	<0.0001

*$P < 0.05$ by non-paired Student's *t*-test.
Adjusted ORs were calculated by multiple logistic regression analysis after adjustment for age, sex, and BMI overall and after adjustment for age and BMI in men and women.
BMI, body mass index; mJSW, minimum joint space width; OR, odds ratio; CI, confidence interval.

57.9% (sensitivity 0.49, specificity 0.84, AUC 0.70, 95% CI 0.64–0.76), respectively. In women, the threshold values of medial/lateral mJSW for pain at the right and left knees were 57.9% (sensitivity 0.57, specificity 0.75, AUC 0.69, 95% CI 0.66–0.73) and 57.7% (sensitivity 0.58, specificity 0.76, AUC 0.71, 95% CI 0.68–0.74), respectively.

Discussion

Joint space narrowing is the primary outcome in studies of knee OA[20], because cartilage damage, which is one of the main causes of knee symptoms, is seen as a smaller mJSW[16]. Previous studies have shown significant associations of joint space narrowing with pain[14,16], though the threshold of joint space width for pain remained unclear. This is the first study to clarify the effect of joint space narrowing on knee pain using a large-scale, population-based, cohort study. In addition, joint space narrowing was evaluated not by categorical grade but by continuous values, using mJSW at the knee. In the present study, mJSW < 3 mm in men and mJSW < 2 mm in women were significantly associated with knee pain, compared with mJSW ≥4 mm, and the OR of mJSW < 1 mm for knee pain was quite high, particularly in men. It was also found that the effect of mJSW on pain was affected by BMI. Medial mJSW/lateral/mJSW < 60% was also significantly associated with knee pain in men and women, compared with medial mJSW/lateral mJSW ≥ 80%. Using ROC curve analysis, the thresholds of mJSW in men and women were found to be approximately 3 mm in men and

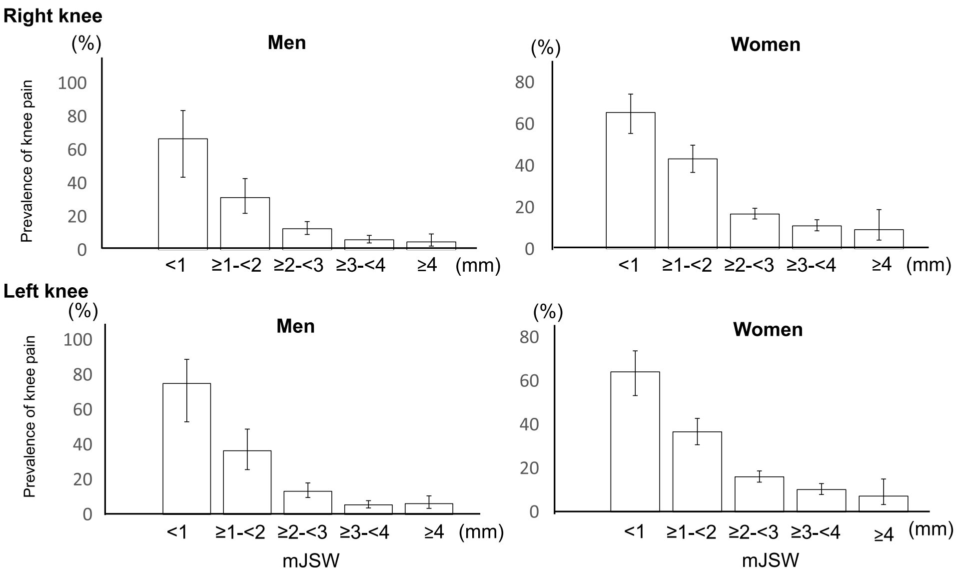

Fig. 1. Prevalence of knee pain by mJSW (mm) in men and women. mJSW, minimum joint space width.

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Table III
OR of knee pain by medial mJSW

	Men				Women			
	Crude OR	95% CI	Adjusted OR	95% CI	Crude OR	95% CI	Adjusted OR	95% CI
Right knee								
<1 mm	39.0	11.9–146.4	39.4	11.6–151.8	18.4	7.7–51.9	12.3	5.0–35.3
≥1–<2 mm	9.0	3.8–23.9	8.5	3.5–23.0	7.4	3.3–19.7	5.9	2.6–15.9
≥2–<3 mm	2.9	1.3–7.2	3	1.4–7.6	2	0.9–5.2	1.8	0.8–4.9
≥3–<4 mm	1.3	0.6–3.3	0.8	0.2–3.2	1.2	0.5–3.3	1.3	0.6–3.5
≥4 mm	1		1		1		1	
Left knee								
<1 mm	45.5	14.9–163.3	38.1	11.9–142.1	22.7	9.4–64.3	14.0	5.7–40.2
≥1–<2 mm	8.7	4.0–20.2	8.5	3.8–20.1	7.3	3.3–19.5	5.3	2.3–14.2
≥2–<3 mm	2.3	1.2–5.0	2.3	1.2–5.1	2.4	1.1–6.4	2.0	0.9–5.3
≥3–<4 mm	0.9	0.4–1.9	0.9	0.4–1.9	1.4	0.6–3.8	1.4	0.6–3.7
≥4 mm	1		1		1		1	

Adjusted ORs were calculated by multiple logistic regression analysis after adjustment for age and BMI.
mJSW, minimum joint space width; CI, confidence interval.

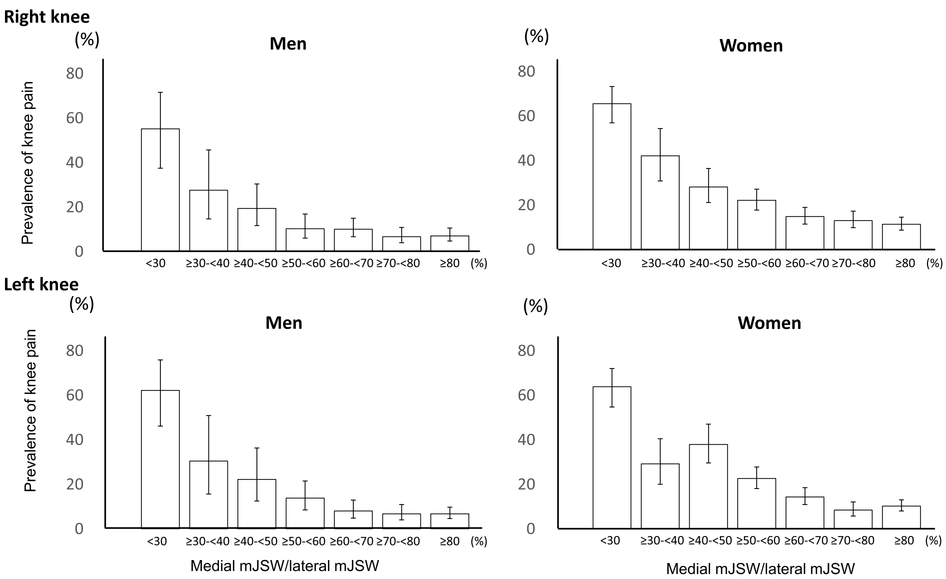

Fig. 2. Prevalence of knee pain by medial mJSW/lateral mJSW (%) in men and women. mJSW, minimum joint space width.

Table IV
OR of knee pain by the ratio of medial mJSW to lateral mJSW

	Men				Women			
	Crude OR	95% CI	Adjusted OR	95% CI	Crude OR	95% CI	Adjusted OR	95% CI
Right knee								
<30%	16.0	6.9–38.2	14.5	6.1–35.0	14.8	9.4–23.7	9.8	6.1–16.0
≥30–<40%	5.0	1.9–12.2	4.4	1.6–10.9	5.7	3.2–10.0	4.2	2.3–7.6
≥40–<50%	3.1	1.5–6.5	2.7	1.2–5.7	3.1	1.9–4.9	2.4	1.5–4.0
≥50–<60%	1.5	0.7–3.0	1.4	0.7–2.9	2.2	1.5–3.3	2.1	1.4–3.2
≥60–<70%	1.5	0.8–2.8	1.5	0.8–2.8	1.4	0.9–2.0	1.3	0.9–2.0
≥70–<80%	0.9	0.5–1.9	0.9	0.5–1.9	1.2	0.8–1.8	1.1	0.7–1.8
≥80%	1		1		1		1	
Left knee								
<30%	23.0	10.7–51.3	18.9	8.6–43.1	15.5	9.8–25.0	10.3	6.4–16.9
≥30–<40%	6.1	2.2–15.8	5.7	2.0–14.8	3.6	2.0–6.4	2.8	1.5–5.0
≥40–<50%	4.0	1.7–8.8	3.6	1.5–8.0	5.4	3.4–8.6	4.3	2.7–7.0
≥50–<60%	2.2	1.1–4.4	2.1	1.0–4.1	2.6	1.7–3.8	2.3	1.5–3.4
≥60–<70%	1.2	0.6–2.4	1.2	0.6–2.4	1.5	0.97–2.2	1.4	0.9–2.1
≥70–<80%	1.0	0.5–1.9	1.0	0.5–2.0	0.8	0.5–1.3	0.8	0.5–1.3
≥80%	1		1		1		1	

Adjusted ORs were calculated by multiple logistic regression analysis after adjustment for age and BMI.
mJSW, minimum joint space width; CI, confidence interval.

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2 mm in women, while those of medial mJSW/lateral mJSW were approximately 60% in both men and women.

Although much effort has been devoted toward a definition of knee pain, the correlation with radiographic severity of knee OA was not as strong as one would expect[4,8–10]. In fact, our previous study showed that the OR of severe knee OA defined as KL grade 3 or 4 for knee pain was 8.6 in men and 4.4 in women[4], which was significant, but the OR was not as high as expected. One of the reasons for this is that knee pain may arise from a variety of structures other than joint cartilage, such as menisci, synovium, ligaments, bursae, bone, and bone marrow[26–30]. Another reason may be due to the definition of knee OA. Knee OA is characterized by the pathological features of joint space narrowing and osteophytosis. However, most conventional systems for grading radiographic severity have been categorical grades, such as KL grading[11], which cannot assess joint space narrowing individually. Several studies have shown that knee OA has a strong effect on QOL[31–34], but in these studies, knee OA was defined by categorical grades such as KL grade or American College of Rheumatology (ACR) grade, total knee arthroplasty, and self-questionnaire. In addition, joint space narrowing was separately evaluated using a radiographic atlas of individual features published by the Osteoarthritis Research Society International (OARSI) in 1995[35] and revised in 2007[36]. Chan *et al.* examined the association of joint space narrowing and duration of pain in patients with knee OA using categorical methods[14]. However, the grading is still limited in reproducibility and sensitivity due to the subjective judgment of individual observers and the categorical classification. Furthermore, because categorical methods are statistically less powerful than continuous methods, the association between pain and knee OA might have been underestimated in previous studies. Kinds *et al.* measured joint space width and found significant associations with clinical outcomes[16], but the threshold of joint space width for clinical outcomes remained unclear. In the present study, to overcome this problem, joint space width was evaluated using a fully automatic system, and the OR of mJSW <1 mm for knee pain was quite high, particularly in men, and it was possible to establish the threshold values of mJSW for knee pain, which may indicate that mJSW is better for diagnosing knee OA than KL grade. In the present study, 6% of men with mJSW <3 mm and 14% of women with mJSW <2 mm, which were the threshold values in the present study, had knee pain. In addition, our previous study showed that 10% of men without knee OA and 20% of women without knee OA had knee pain[4]. These subjects have knee pain, despite having no radiographical changes. This indicates that at least 10% and 20% of knee pain in men and women, respectively, may be explained by factors other than radiographical changes.

In the present study, sex differences were found in the association of mJSW with pain. These discrepancies between the sexes are explained by several factors. First, women are more susceptible to pain than men[4]. In fact, our previous study showed that the OR for knee pain in women without radiographic knee OA (KL = 0/1) was greater than that in men without radiographic knee OA[4]. In the present study, the prevalence of knee pain was 5–6% in men with mJSW ≥4 mm, while it was 7–9% in women with mJSW ≥4 mm. This high prevalence of knee pain in women with mJSW ≥4 mm, which are reference data, may partly explain the lower OR for knee pain in women than men. Second, men with normal knees had wider joint space widths than women with normal knees. Our previous study showed that mean mJSW in men with KL = 0 was approximately 4 mm, while that in women with KL = 0 was approximately 3 mm[25]. This means that subjects with mJSW = 3 mm have a normal knee in women, while they have joint space narrowing at the knee in men. In addition, mJSW = 1 mm means 75% cartilage loss in men, while it represent 67% cartilage loss in women. In fact, the associations of medial mJSW/lateral mJSW with pain were similar in men and women, which may also explain the lower OR for knee pain in women than men.

Obesity is one of the few established risk factors for knee OA and pain[17–23]. A clinical review article reported that 69% of knee replacements in middle-aged females can be attributed to obesity[22], and it has been estimated that, if overweight and obese individuals reduced their weight to reach normal BMIs, about 50% of knee OA cases would be eliminated[21]. However, to the best of our knowledge, there are no population-based studies that assess the effect of obesity on the association of joint space narrowing with pain. In the present study, a distinct effect of BMI was found on the association of mJSW with pain. For example, at the right knee in women, mJSW ≥1–<2 mm in women with BMI ≥23 kg/m^2 was significantly associated with pain, while mJSW ≥1–<2 mm in women with BMI <23 kg/m^2 was not, compared to mJSW≥4 mm with BMI <23 kg/m^2. In addition, the OR was similar between mJSW ≥1–<2 mm with BMI ≥23 kg/m^2 and mJSW <1 mm with BMI <23 kg/m^2. These indicate that weight loss may be an effective way to reduce knee pain even when joint space narrowing is present at the knee.

There are limitations in the present study. First, this was a large-scale, population-based, cross-sectional study of baseline data. Thus, causal relationships could not be determined. The ROAD study is a longitudinal survey, so further progress may help elucidate any causal relationships. Second, the threshold in the present study was calculated by a particular statistical method, but certain situations may favor sensitivity over specificity, e.g., screening. In addition, the sensitivity and specificity were modest in the present study. These may be partly explained by the fact that knee pain can arise from a variety of structures other than joint cartilage, such as menisci, synovium, ligaments, bursae, bone, and bone marrow[26–30], which are unable to be assessed radiologically. However, using the KOACAD system, it was possible to demonstrate strong associations of mJSW with knee pain and to establish the threshold of mJSW for knee pain, which may indicate that mJSW is more useful than categorical methods for diagnosing knee OA. Third, cases with lateral knee OA were excluded, leading to a selective sample. One reason for excluding lateral knee OA is that most knee OA in Japan is medial type. There are racial differences in the ratio of lateral to medial knee OA, and previous studies showed that the ratio of lateral to medial knee OA was 0.20 in Caucasian and 0.64 in Chinese populations[37]. In the Amsterdam OA Cohort, lateral knee OA is rather common, and it occurs in association with OA features in other knee compartments[38]. However, our previous study showed that the ratio of lateral to medial knee OA was 0.10 in Japan, which indicates that knee OA was medial type. The other reason for excluding lateral knee OA is that medial and lateral knee OA have distinct characteristics, because, in medial knee OA, there is narrowing of the medial mJSW, while in lateral knee OA, there is narrowing of the lateral mJSW. Thus, the effect of medial mJSW on pain may be obscured by lateral knee OA, because medial joint space width may not change or be larger in lateral knee OA. Thus, the aim of the present study was to clarify the effect of medial knee OA on pain, although excluding lateral OA leads to a selective sample. Lastly, it was not possible to clarify whether the threshold in the present study can apply to other races or populations, because the prevalence of knee OA and the ratio of medial knee OA/lateral knee OA are quite different among races[4,37,38], and the association of knee OA with pain among them may be quite different. To clarify this, international collaborative studies using the KOACAD system are needed.

In conclusion, the present cross-sectional study using a large population from the ROAD study showed that joint space narrowing was strongly associated with knee pain. The threshold of mJSW with knee pain was approximately 3 mm in men and 2 mm

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in women, while the threshold of medial mJSW/lateral mJSW was approximately 60% in both men and women. BMI was found to have a distinct effect on the association of mJSW with pain. Further studies, along with continued longitudinal surveys in the ROAD study, will help improve our understanding of the mechanisms of joint space narrowing at the knee and their relationship with pain.

Acknowledgments

This work was supported by Grants-in-Aid for Scientific Research (S19109007, B20390182, C20591737, C20591774), for Young Scientists (A18689031), and for Exploratory Research (19659305) from the Japanese Ministry of Education, Culture, Sports, Science, and Technology, grants (H17-Men-eki-009, H18-Choujyu-037, H20-Choujyu-009, H21-Chouju-Wakate-011 and H22-Chouju-Wakate-007) from the Ministry of Health, Labour and Welfare, a Research Aid from the Japanese Orthopaedic Association (JOA-Subsidized Science Project Research 2006-1), and Grant No.166 from the Japan Orthopaedics and Traumatology Foundation.

The authors would like to thank Dr Anamizu and members of the Department of Orthopedics; Mr Kutsuma and other members of the Department of Radiology at Tokyo Metropolitan Geriatric Medical Center; Mrs Tomoko Takijiri and other members of the Public Office in Hidakagawa Town; and Mrs Tamako Tsutsumi and Mrs Kanami Maeda, and other members of the Public Office in Taiji Town, for their assistance in locating and scheduling participants for examinations.

Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.joca.2015.01.011.

Author contributions

All authors have made substantial contributions to all three of the following sections:

(1) the conception and design of the study, or acquisition of data, or analysis and interpretation of data;
(2) drafting the article or revising it critically for important intellectual content; and
(3) final approval of the version to be submitted.

Conflicts of interest

There are no conflicts of interest.

References

1. Sharma L, Kapoor D. Epidemiology of osteoarthritis. In: Moskowitz RW, Altman RD, Hochberg MC, Buckwalter JA, Goldberg VM, Eds. Osteoarthritis: Diagnosis and Medical/Surgical Management. 4th edn. Philadelphia: Lippincott Williams & Wilkins; 2007:3–26.
2. Guccione AA, Felson DT, Anderson JJ, Anthony JM, Zhang Y, Wilson PW, *et al*. The effects of specific medical conditions on the functional limitations of elders in the Framingham Study. Am J Public Health 1994;84:351–8.
3. Felson DT, Zhang Y. An update on the epidemiology of knee and hip osteoarthritis with a view to prevention. Arthritis Rheum 1998;41:1343–55.
4. Muraki S, Oka H, Akune T, Mabuchi A, En-yo Y, Yoshida M, *et al*. Prevalence of radiographic knee osteoarthritis and its association with knee pain in the elderly of Japanese population-based cohorts: the ROAD study. Osteoarthritis Cartilage 2009;17:1137–43.
5. Yoshimura N, Muraki S, Oka H, Mabuchi A, En-yo Y, Yoshida M, *et al*. Prevalence of knee osteoarthritis, lumbar spondylosis and osteoporosis in Japanese men and women: the research on Osteoarthritis/Osteoporosis Against Disability (ROAD). J Bone Miner Metab 2009;27:620–8.
6. Ministry of Health, Labour and Welfare. The Outline of the Results of National Livelihood Survey 2010. Available at: http://www.mhlw.go.jp/toukei/saikin/hw/k-tyosa/k-tyosa10/index.html.
7. Linaker CH, Walker-Bone K, Palmer K, Cooper C. Frequency and impact of regional musculoskeletal disorders. Baillieres Best Pract Res Clin Rheumatol 1999;13:197–215.
8. Summers MN, Haley WE, Reveille JD, Alarcon GS. Radiographic assessment and psychologic variables as predictors of pain and functional impairment in osteoarthritis of the knee or hip. Arthritis Rheum 1988;31:204–9.
9. Cicuttini FM, Baker J, Hart DJ, Spector TD. Association of pain with radiological changes in different compartments and views of the knee joint. Osteoarthritis Cartilage 1996;4:143–7.
10. Wluka AE, Wolfe R, Stuckey S, Cicuttini FM. How does tibial cartilage volume relate to symptoms in subjects with knee osteoarthritis? Ann Rheum Dis 2004;63:264–8.
11. Kellgren JH, Lawrence JS, Eds. The Epidemiology of Chronic Rheumatism: Atlas of Standard Radiographs of Arthritis. Oxford: Blackwell Scientific; 1963.
12. Muraki S, Oka H, Akune T, En-yo Y, Yoshida M, Suzuki T, *et al*. Independent association of joint space narrowing and osteophyte formation at the knee with health-related quality of life in Japan: a cross-sectional study. Arthritis Rheum 2011;63:3859–64.
13. Altman R, Brandt K, Hochberg M, Moskowitz R. Design and conduct of clinical trials in people with osteoarthritis. Osteoarthritis Cartilage 1996;4:217–43.
14. Chan WP, Huang GS, Hsu SM, Chang YC, Ho WP. Radiographic joint space narrowing in osteoarthritis of the knee: relationship to meniscal tears and duration of pain. Skeletal Radiol 2008;37:917–22.
15. Oka H, Muraki S, Akune T, Mabuchi A, Suzuki T, Yoshida H, *et al*. Fully automatic quantification of knee osteoarthritis severity on plain radiographs. Osteoarthritis Cartilage 2008;16:1300–6.
16. Kinds MB, Marijnissen AC, Bijlsma JW, Boers M, Lafeber FP, Welsing PM. Quantitative radiographic features of early knee osteoarthritis: development over 5 years and relationship with symptoms in the CHECK cohort. J Rheumatol 2014;40:58–65.
17. Schouten JSAG. A 12 Year Follow Up Study on Osteoarthritis of the Knee in the General Population [thesis]. Rotterdam: Erasmus University Medical School; 1991.
18. Hart DJ, Doyle DV, Spector TD. Incidence and risk factors for radiographic knee osteoarthritis in middle-aged women: the Chingford Study. Arthritis Rheum 1999;42:17–24.
19. Cooper C, Snow S, McAlindon TE, Kellingray S, Stuart B, Coggon D, *et al*. Risk factors for the incidence and progression of radiographic knee osteoarthritis. Arthritis Rheum 2000;43:995–1000.
20. Altman RD, Fries JF, Bloch DA, Carstens J, Cooke TD, Genant H, *et al*. Radiographic assessment of progression in osteoarthritis. Arthritis Rheum 1987;30:1214–25.
21. Coggon D, Reading I, Croft P, McLaren M, Barrett D, Cooper C. Knee osteoarthritis and obesity. Int J Obes Relat Metab Disord 2001;25:622.
22. D'Arcy Y. Pain and obesity. Nurs Manage 2012;43:21–6.

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23. MacFarlane G, de Silva V, Jones G. The relationship between body mass index across the life course and knee pain in adulthood: results from the 1958 birth cohort study. Rheumatology 2011;50:2251–6.
24. Yoshimura N, Muraki S, Oka H, Kawaguchi H, Nakamura K, Akune T. Cohort profile: research on osteoarthritis/osteoporosis against disability study. Int J Epidemiol 2010;39:988–95.
25. Oka H, Muraki S, Akune T, Nakamura K, Kawaguchi H, Yoshimura N. Normal and threshold values of joint space width, joint space area, osteophyte area and fibro-tibial angle using a computer-assisted measuring system (KOACAD) to evaluate knee osteoarthritis: the ROAD study. J Orthop Sci 2010;15:781–9.
26. Saito T, Koshino T. Distribution of neuropeptides in synovium of the knee with osteoarthritis. Clin Orthop Relat Res 2000;376:172–82.
27. Bollet AJ. Edema of the bone marrow can cause pain in osteoarthritis and other diseases of bone and joints. Ann Intern Med 2001;134:591–3.
28. Teichtahl AJ, Wluka AE, Morris ME, Davis SR, Cicuttini FM. The relationship between the knee adduction moment and knee pain in middle-aged women without radiographic osteoarthritis. J Rheumatol 2006;33:1845–8.
29. Thorp LE, Sumner DR, Wimmer MA, Block JA. Relationship between pain and medial knee joint loading in mild radiographic knee osteoarthritis. Arthritis Rheum 2007;57:1254–60.
30. Felson DT, Niu J, Guermazi A, Roemer F, Aliabadi P, Clancy M, *et al*. Correlation of the development of knee pain with enlarging bone marrow lesions on magnetic resonance imaging. Arthritis Rheum 2007;56:2986–92.
31. Woo J, Lau E, Lee P, Kwok T, Lau WC, Chan C, *et al*. Impact of osteoarthritis on quality of life in a Hong Kong Chinese population. J Rheumatol 2004;31:2433–8.
32. Brazier JE, Harper R, Munro J, Walters SJ, Snaith ML. Generic and condition-specific outcome measures for people with osteoarthritis of the knee. Rheumatology (Oxford) 1999;38:870–7.
33. Hill CL, Parsons J, Taylor A, Leach G. Health related quality of life in a population sample with arthritis. J Rheumatol 1999;26:2029–35.
34. Muraki S, Akune T, Oka H, En-yo Y, Yoshida M, Saika A, *et al*. Association of radiographic and symptomatic knee osteoarthritis with health-related quality of life in a population-based cohort study in Japan: the ROAD study. Osteoarthritis Cartilage 2010;18:1227–34.
35. Altman RD, Hochberg M, Murphy Jr WA, Wolfe F, Lequesne M. Atlas of individual radiographic features in osteoarthritis. Osteoarthritis Cartilage 1995;3(Suppl A):3–70.
36. Altman RD, Gold GE. Atlas of individual radiographic features in osteoarthritis, revised. Osteoarthritis Cartilage 2007;15(Suppl A):A1–A56.
37. Felson DT, Nevitt MC, Zhang Y, Aliabadi P, Baumer B, Gale D, *et al*. High prevalence of lateral knee osteoarthritis in Beijing Chinese compared with Framingham caucasian asubjects. Arthritis Rheum 2002;46:1217–22.
38. van der Esch M, Knol DL, Schaffers IC, Reiding DJ, van Schaardenburg D, Knoop J, *et al*. Osteoarthritis of the knee: multicompartmental or compartmental disease? Rheumatology (Oxford) 2014;53:540–6.

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J Bone Miner Metab (2015) 33:186–191
DOI 10.1007/s00774-014-0573-y

ORIGINAL ARTICLE

Incidence of disability and its associated factors in Japanese men and women: the Longitudinal Cohorts of Motor System Organ (LOCOMO) study

Noriko Yoshimura · Toru Akune · Saeko Fujiwara · Yoko Shimizu · Hideyo Yoshida · Yuji Nishiwaki · Akihiro Sudo · Go Omori · Munehito Yoshida · Hiroshi Shimokata · Takao Suzuki · Shigeyuki Muraki · Hiroyuki Oka · Kozo Nakamura

Received: 27 August 2013 / Accepted: 19 January 2014 / Published online: 27 April 2014

Abstract We investigated the incidence of disability and its risk factors in older Japanese adults to establish an evidence-based disability prevention strategy for this population. For this purpose, we used data from the Longitudinal Cohorts of Motor System Organ (LOCOMO) study, initiated in 2008 to integrate information from cohorts in nine communities across Japan: Tokyo (two regions), Wakayama (two regions), Hiroshima, Niigata, Mie, Akita, and Gunma prefectures. We examined the annual occurrence of disability from 8,454 individuals (2,705 men and 5,749 women) aged $\geq$65 years. The estimated incidence of disability was 3.58/100 person-years (p-y) (men: 3.17/100 p-y; women: 3.78/100 p-y). To determine factors associated with disability, Cox's proportional hazard model was used, with the occurrence of disability as an objective variable and age (+1 year), gender (vs. women), body build (0: normal/overweight range, BMI 18.5–27.5 kg/m^2; 1: emaciation, BMI <18.5 kg/m^2; 2: obesity, BMI >27.5 kg/m^2), and regional differences (0: rural areas including Wakayama, Niigata, Mie, Akita, and Gunma vs. 1: urban areas including Tokyo and Hiroshima) as explanatory variables. Age, body build, and regional difference significantly influenced the occurrence of disability (age, +1 year: hazard ratio 1.13, 95 % confidence interval 1.12–1.15, $p < 0.001$; body build, vs. emaciation: 1.24, 1.01–1.53, $p = 0.041$; body build, vs. obesity: 1.36, 1.08–1.71, $p = 0.009$; residence, vs. living in rural areas: 1.59, 1.37–1.85, $p < 0.001$). We concluded that higher age,

N. Yoshimura (✉) · H. Oka
Department of Joint Disease Research, 22nd Century Medical and Research Center, Graduate School of Medicine, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8655, Japan
e-mail: yoshimuran-ort@h.u-tokyo.ac.jp

T. Akune · S. Muraki
Department of Clinical Motor System Medicine, 22nd Century Medical and Research Center, Graduate School of Medicine, University of Tokyo, Tokyo, Japan

S. Fujiwara
Hiroshima Atomic Bomb Causality Council, Hiroshima, Japan

Y. Shimizu · H. Yoshida
Tokyo Metropolitan Institute of Gerontology, Tokyo, Japan

Y. Nishiwaki
Department of Environmental and Occupational Health, School of Medicine, Toho University, Tokyo, Japan

A. Sudo
Department of Orthopaedic Surgery, Mie University Graduate School of Medicine, Mie, Japan

G. Omori
Center for Transdisciplinary Research, Institute for Research Promotion, Niigata University, Niigata, Japan

M. Yoshida
Department of Orthopedic Surgery, School of Medicine, Wakayama Medical University, Wakayama, Japan

H. Shimokata
Graduate School of Nutritional Sciences, Nagoya University of Arts and Sciences, Aichi, Japan

T. Suzuki
National Center for Geriatrics and Gerontology, Aichi, Japan

K. Nakamura
National Rehabilitation Center for Persons with Disabilities, Saitama, Japan

both emaciation and obesity, and living in rural areas would be risk factors for the occurrence of disability.

Keywords Nation-wide population-based cohort study · Epidemiology · Incidence · Disability · Body build

Introduction

In Japan, the proportion of the population aged 65 years or older has increased rapidly over the years. In 1950, 1985, 2005, and 2010, this proportion was 4.9, 10.3, 19.9, and 23.0 %, respectively [1]. Further, this proportion is estimated to reach 30.1 % in 2024 and 39.0 % in 2051 [2]. The rapid aging of Japanese society, unprecedented in world history, has led to an increase in the number of disabled elderly individuals requiring support or long-term care. The Japanese government initiated the national long-term care insurance system in April 2000 in adherence with the Long-Term Care Insurance Act [3]. The aim of the national long-term care insurance system was to certify the level of care needed by elderly adults and to provide suitable care services to them according to the levels of their long-term care needs. According to the recent National Livelihood Survey by the Ministry of Health, Labour and Welfare in Japan, the number of elderly individuals certified as needing care services increases annually, having reached 5 million in 2011 [4].

However, few prospective, longitudinal, and cross-national studies have been carried out to inform the development of a prevention strategy against disability. To establish evidence-based prevention strategies, it is critically important to accumulate epidemiologic evidence, including the incidence of disability, and identify its risk factors. However, few studies have attempted to estimate the incidence of the disability and its risk factors by using population-based cohorts. In addition, to identify the incidence of disability, a study should have a large number of subjects. Further, to determine regional differences in epidemiological indices, a survey of cohorts across Japan is required.

The Longitudinal Cohorts of Motor System Organ (LOCOMO) study was initiated in 2008, through a grant from Japan's Ministry of Health, Labour and Welfare, for the prevention of knee pain, back pain, bone fractures, and subsequent disability. It aimed to integrate data gathered from cohorts from 2000 onwards and follow-up surveys from 2006 onwards, using a unified questionnaire, with an ultimate goal being the prevention of musculoskeletal diseases. The present study specifically aims at using LOCOMO data, which is based on the long-term care insurance system, to investigate the occurrence of disability in order to clarify its incidence and risk factors, especially in terms of body build and regional differences.

Materials and methods

Participants were residents of nine communities located in Tokyo (two regions: Tokyo-1, principal investigators (PIs): Shigeyuki Muraki, Toru Akune, Noriko Yoshimura, Kozo Nakamura; Tokyo-2, PIs: Yoko Shimizu, Hideyo Yoshida, Takao Suzuki), Wakayama [two regions: Wakayama-1 (mountainous region) and Wakayama-2 (coastal region), PIs: Noriko Yoshimura, Munehito Yoshida], Hiroshima (PI: Saeko Fujiwara), Niigata (PI: Go Omori), Mie (PI: Akihiro Sudo), Akita (PI: Hideyo Yoshida), and Gunma (PI: Yuji Nishiwaki) prefectures [5]. Figure 1 shows the location of each cohort in Japan.

Disability in the present study was defined as 'cases requiring long-term care', as determined by the long-term care insurance system. The procedure for identifying these cases is as follows: (1) each municipality establishes a long-term care approval board consisting of clinical experts, physicians, and specialists at the Division of Health and Welfare in each municipal office; (2) The long-term care approval board investigates the insured person by using an interviewer-administered questionnaire consisting of 82 items regarding mental and physical conditions, and makes a screening judgement based on the opinion of a regular doctor; (3) 'Cases requiring long-term care' are determined according to standards for long-term care certification that are uniformly and objectively applied nationwide [6].

In order to identify the incidence of disability, data were collected from participants aged 65 years and older within the above-mentioned cohorts. In Japan, most individuals certified as 'cases requiring long-term care' are 65 years and older. Table 1 shows the number of subjects per region, as well as the data obtained within the first year of the observation. The smallest cohort consisted of 239 subjects, residing in Mie, while the largest consisted of 1,758, who resided in Gunma.

The earliest baseline data were collected in 2000 in Hiroshima, while the latest were obtained in 2008 in Tokyo-2. The cohorts were subsequently followed until 2012. Data regarding participants' deaths, changes of residence, and occurrence or non-occurrence of certified disability were gathered annually from public health centres of the participating municipalities. As an index of body build, baseline data on participants' height and weight were collected, and used to calculate body mass index (BMI, kg/m^2). Participants were classified as follows: normal or overweight (BMI = 18.5–27.5), obese (BMI >27.5), or emaciated (BMI <18.5). These cut-off points were determined according to a WHO report [7]. From 2008 onwards, follow-up data was obtained using the unified questionnaire.

All participants provided written informed consent, and the study was conducted with the approval of the ethics committees of the University of Tokyo (nos. 1264 and 1326), the Tokyo Metropolitan Institute of Gerontology

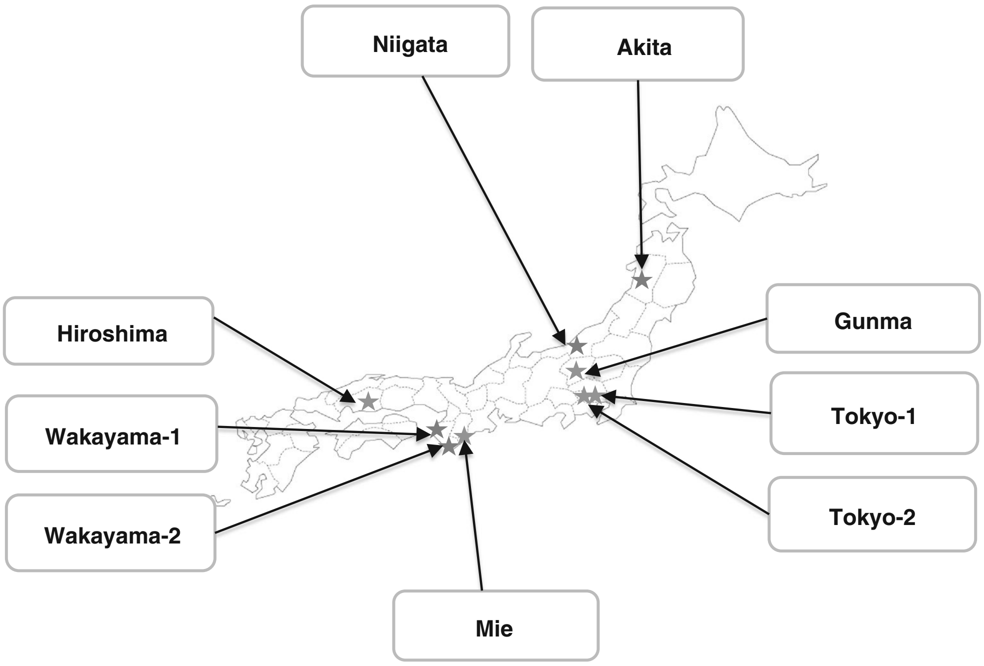

Fig. 1 Location of nine regions from which the study cohorts were selected

Table 1 Number of subjects classified by regions of each cohort

Region	Start year	Total	Men	Women
Tokyo-1	2005	1,332	461	871
Tokyo-2	2008	1,453	59	1,394
Wakayama-1 (Mountainous)	2005	610	239	371
Wakayama-2 (Coastal)	2006	357	129	228
Hiroshima	2000	1,341	351	990
Niigata	2007	805	343	462
Mie	2001	239	95	144
Akita	2006	559	223	336
Gunma	2005	1,758	805	953
Total		8,454	2,705	5,749

(no. 5), Wakayama (no. 373), the Radiation Effects Research Foundation (RP 03-89), Niigata University (no. 446), Mie University (nos. 837 and 139), Keio University (no. 16–20), and the National Center for Geriatrics and Gerontology (no. 249). Careful consideration was given to ensure the safety of the participants during all of the study procedures.

Statistical analysis

All statistical analyses were performed using STATA (STATA Corp., College Station, Texas, USA). Differences in proportions were compared using the chi-squared test. Differences in continuous variables were tested using an analysis of variance (ANOVA) with Scheffe's least significant difference test for post-hoc pairwise comparisons. To test the association between the occurrence of disability and other variables, Cox's proportional hazard regression analysis was used. Hazard ratios (HRs) were estimated using the occurrence of disability as an objective variable (0: non-occurrence, 1: occurrence) and the following explanatory variables: age (± 1 year), gender (vs. female), body build (0: normal and overweight vs. 1: emaciation vs. 2: obesity), and regional differences (0: rural areas, including Wakayama-1, Wakayama-2, Niigata, Mie, Akita, and Gunma vs. 1: urban areas, including Tokyo-1, Tokyo-2, and Hiroshima). All p values and 95 % confidence intervals (CI) of two-sided analyses are presented.

Results

Table 2 shows the number of participants classified by age and gender. The majority of participants were 75–79 years old; two-thirds of the participants were women.

Selected characteristics of the study population, including age, height, weight, and BMI, are shown in Table 3. The mean values of age, height, and weight were significantly greater in women than in men ($p < 0.001$), but BMI did not significantly differ between men and women ($p = 0.479$).

The estimated incidence of disability is shown in Fig. 2. In total, the incidence of disability among individuals aged 65 years and older was 3.58/100 person-years (p-y) (p-y; men: 3.17/100 p-y; women: 3.78/100 p-y). The incidence of disability was 0.83/100 p-y, 1.70/100 p-y, 3.00/100 p-y,

Table 2 Number of subjects classified by age and gender

Age strata (years)	Total (%)	Men (%)	Women (%)
65–69	1,390 (16.4)	555 (20.5)	835 (14.5)
70–74	1,704 (20.2)	668 (24.7)	1,036 (18.0)
75–79	2,923 (34.6)	812 (30.0)	2,111 (36.7)
80–84	1,810 (21.4)	463 (17.1)	1,347 (23.4)
≥85	627 (7.4)	207 (7.7)	420 (7.3)
Total	8,454 (100.0)	2,705 (100.0)	5,749 (100.0)

Table 3 Baseline characteristics of subjects classified by age and gender

Variables	Men	Women	*p* (men vs. women)
Age (years)	75.3 (6.4)	76.5 (6.0)	<0.001
Height (cm)	160.5 (6.5)	147.7 (6.1)	<0.001
Weight (kg)	58.7 (9.1)	49.8 (8.4)	<0.001
BMI (kg/m^2)	22.7 (2.9)	22.8 (3.5)	0.479
Living in rural area (%)	84.8	58.5	<0.001

Values are represented as mean (standard deviation)

BMI body mass index

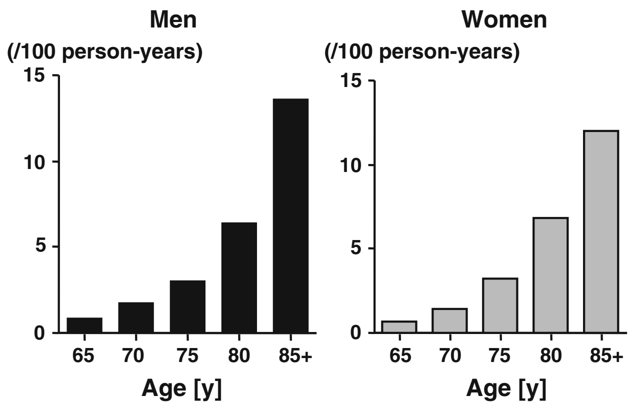

Fig. 2 Incidence of disability according to age and gender

6.36/100 p-y, and 13.54/100 p-y in 65–69-, 70–74-, 75–79-, 80–84-, and ≥85-year-old men, respectively. In women, the incidence of disability was 0.71/100 p-y, 1.40/100 p-y, 3.25/100 p-y, 6.85/100 p-y, and 12.01/100 p-y in the age ranges of 65–69, 70–74, 75–79, 80–84, and 85 or more years, respectively (Table 4).

Cox's proportional hazard regression analysis showed that occurrence of disability was significantly influenced by age, body build, and regional differences, but not gender (age, +1 years: hazard ratio 1.13, 95 % confidence interval 1.12–1.15, $p < 0.001$; sex, vs. female: 1.13, 0.97–1.31, $p = 0.125$; body build: emaciation: 1.24, 1.01–1.53, $p = 0.041$; body build; obesity: 1.36, 1.08–1.71, $p = 0.009$; residence, vs. living in rural areas: 1.59, 1.37–1.85, $p < 0.001$).

Discussion

Using the data of the LOCOMO study, we determined the incidence of disability and identified age, emaciation, obesity, and residence in rural areas as risk factors for the occurrence of disability. More specifically, we integrated data collected from subjects aged 65 and older in individual cohorts established in nine regions across Japan to determine the incidence of disability in the specified regions. We found an association between various risk factors and disability; these include age, emaciation, and obesity, as well as residence in rural areas.

The LOCOMO study was the first nation-wide prospective study to track a large number of the subjects from several population-based cohorts. The LOCOMO study aimed to integrate information from these cohorts, to prevent musculoskeletal diseases and subsequent disability. The data shed light on the prevalence and characteristics of targeted clinical symptoms such as knee pain or lumbar pain, or defined diseases such as knee osteoarthritis (KOA), lumbar spondylosis (LS), and osteoporosis (OP), as well as their prognosis in reference to either mortality or chances of developing a disability. In the present study, we also

Table 4 Hazard ratios (HRs) of potential risk factors for the occurrence and non-occurrence of disability

Disability (occurrence vs. non-occurrence)				
Explanatory variable	Reference	HR	95 % confidence interval	*p*
Age (years)	+1 year	1.13	1.12–1.15	<0.001***
Gender	0: men, 1: women	1.13	0.97–1.31	0.125
Body build	0: 18.5 ≤ BMI ≤ 27.5, 1: BMI < 18.5	1.24	1.01–1.53	0.041*
	0: 18.5 ≤ BMI ≤ 27.5, 2: BMI >27.5	1.36	1.08–1.71	0.009**
Type of residential area	0: urban area, 1: rural area	1.59	1.37–1.85	<0.001***

BMI body mass index

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

compared the above-mentioned symptoms, diseases, and prognoses between regions.

The overall incidence of disability among individuals aged 65 years and older was 3.58/100 person-years. When results from the present study are applied to the total age-sex distribution derived from the Japanese census in 2010 [1], it could be assumed that 1,110,000 people (410,000 men and 700,000 women) aged 65 years and older are newly affected by disability and require support. It has been reported that the total number of subjects who were certified as needing care increases annually [4]; however, few of these reports estimate the number of newly certified cases through a population-based cohort. Clarifying the incidence of disability and its risk factors was viewed as the first step toward preventing its occurrence.

Emaciation and obesity were both identified as risk factors for disability; thus, there appears to be a U-shaped association between BMI and disability as well as between BMI and mortality [8, 9]. According to the recent National Livelihood Survey, the leading cause of disabilities that require support and long-term care is cardiovascular disease (CVD), followed by dementia, senility, osteoarthrosis, and fractures [4]. Obesity is an established risk factor for chronic diseases, including hypertension, dyslipidemia, and diabetes mellitus, which increase the risk for CVD [10]; in turn, CVD causes ADL-related disabilities in older adults. In addition, numerous reports have shown an association between overweight or obesity and KOA [11–17]. In previous reports, we found a significant association between BMI and not only the presence of KOA, but also the occurrence and progression of KOA [18, 19]. In addition, emaciation is an established risk factor for OP and OP-related fractures [20]. OP might be related to low nutrition due to chronic wasting diseases.

The current study also found an association between living in a rural area and the occurrence of disability. There have been reports of regional differences in the certification rate of disability in Japan. For instance, Kobayashi reported a prefectural difference in the certification rate of disability, which was particularly prominent among individuals aged 75 years and older at lower nursing care levels in the long-term care insurance system [21]. In addition, Shimizutani et al. [22] pointed out that the financial condition of the insurer influenced the certification rate of disability. Further, Nakamura found that the certification of lower care levels was influenced by social and/or individual factors, such as the type of service provider, the application rate, and number of medical treatment recipients. However, certification of advanced nursing care levels was influenced by CVD and lifestyle-related diseases [23].

Other than differences in the social backgrounds of individuals in each prefecture, we posited that regional differences (rural or urban) in the occurrence of disability might be due to differences in the frequency of diseases and ailments that cause disability in each area. The prevalence of musculoskeletal diseases, such as KOA and LS, differs among mountainous, coastal, and urban areas [24]. Evidence also exists for regional differences in the incidence of hip fractures [25–27]. It was also found that mortality and incidence of ischemic stroke, which is related to CVD, was higher in the northeastern than in the southwestern part of Japan [28]. However, there is currently no information on regional differences in dementia prevalence and incidence in Japan. In general, differences in the frequency of diseases causing disability might influence regional differences in disability rates. In relation to this, in a future study on follow-up data from the LOCOMO study, it might be necessary to collect information on the prevalence and frequency of diseases that cause disability, such as musculoskeletal diseases, CVD, and dementia. This future study should also attempt to clarify mutual associations among risk factors for disability, so as to inform the development of measures for its primary prevention.

Despite its contribution to existing knowledge, the present study has several limitations. First, its sample does not truly represent the entire Japanese population, because our cohorts were not drawn from the northernmost and southernmost parts of Japan (e.g., Okinawa prefecture or Hokkaido prefecture). This limitation must be taken into consideration, especially when determining the generalisability of the results. However, the LOCOMO study is the first large-scale, population-based prospective study with approximately 9,000 participants aged 65 years and older. Second, data collected from the cohorts were not uniform, as certain information was obtained from some participants, but not others. For example, the X-ray examinations of subjects' knees were performed in Tokyo-1, Wakayama-1, Wakayama-2, Niigata, and Mie; lumbar spine X-ray examinations were performed in Tokyo-1, Wakayama-1, Wakayama-2, Hiroshima, and Mie. Therefore, we could not evaluate the presence or absence of KOA, LS, or OP as a possible cause of disability by using the data of the entire LOCOMO study. Further investigation following the integration of information on musculoskeletal disorders would enable us to evaluate all the factors that are associated with disability.

Nevertheless, our study has several strengths. As mentioned above, the large sample size is the study's biggest strength. The second strength is that we collected data from nine cohorts across Japan, which enabled us to compare regional differences in the incidence of disability. In addition, the variety of measures and assessments used in this study enabled us to collect a substantial amount of detailed information. However, given the fact that not all of the measures were administered in all cohorts, regional selection bias in the analysis should be considered when interpreting the results.

Acknowledgments This work was supported by grants from Grant-in-Aid for H17-Men-eki-009 (Director, Kozo Nakamura), H20-Choujyu-009 (Director, Noriko Yoshimura), H23-Choujyu-002 (Director, Toru Akune), and H-25-Chojyu-007 (Director, Noriko Yoshimura) of the Ministry of Health, Labour and Welfare. Further grants were provided by Scientific Research B24659317, B23390172, B20390182, and Challenging Exploratory Research 24659317 to Noriko Yoshimura; B23390357 and C20591737 to Toru Akune; B23390356, C20591774, and Challenging Exploratory Research 23659580 to Shigeyuki Muraki; Challenging Exploratory Research 24659666, 21659349, and Young Scientists A18689031 to Hiroyuki Oka, and collaborative research with NSF 08033011-00262 (Director, Noriko Yoshimura) from the Ministry of Education, Culture, Sports, Science and Technology in Japan. The sponsors did not contribute to the study design, data collection, data analysis, data interpretation, or the writing of the manuscript.

The authors wish to thank Ms. Kyoko Yoshimura, Mrs. Toki Sakurai, and Mrs. Saeko Sahara for their assistance with data consolidation and administration.

Conflict of interest All authors declare no conflicts of interest.

References

1. Statistical Bureau, Ministry of Internal Affairs and Communication. Population Count based on the 2010 Census Released. http://www.stat.go.jp/english/data/kokusei/pdf/20111026.pdf. Accessed 26 Feb 2014
2. National Institute of Population and Society Research (2012) Population projections for Japan (January 2012): 2011–2060. http://www.ipss.go.jp/site-ad/index_english/esuikei/ppfj2012.pdf. Accessed 26 Feb 2014
3. Long-Term Care Insurance Act. http://www.japaneselawtranslation.go.jp/law/detail_main?id=94&vm=4&re=. Accessed 26 Feb 2014
4. Ministry of Health, Labour and Welfare (2010) Outline of the results of National Livelihood Survey. http://www.mhlw.go.jp/toukei/saikin/hw/k-tyosa/k-tyosa10/4-2.html. Accessed 26 Feb 2014 (in Japanese)
5. Yoshimura N, Nakamura K, Akune T, Fujiwara S, Shimizu Y, Yoshida H, Omori G, Sudo N, Nishiwaki Y, Yoshida M, Shimokata H (2013) The longitudinal cohorts of motor system organ (LOCOMO) study. Nippon Rinsho 71:642–645 (in Japanese)
6. Ministry of Health, Labour and Welfare. Long-term care insurance in Japan. http://www.mhlw.go.jp/english/topics/elderly/care/index.html. Accessed 26 Feb 2014
7. WHO Expert Consultation (2004) Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet 363:157–163
8. Zheng W, McLerran DF, Rolland B, Zhang X, Inoue M et al (2011) Association between body-mass index and risk of death in more than 1 million Asians. N Engl J Med 364:719–729
9. Whitlock G, Lewington S, Sherliker P, Clarke R, Emberson J, Halsey J, Qizilbash N, Collins R, Peto R, Prospective Studies Collaboration (2009) Body-mass index and cause-specific mortality in 900,000 adults: collaborative analyses of 57 prospective studies. Lancet 373:1083–1096
10. Haslam DW, James WP (2005) Obesity. Lancet 366:1197–1209
11. Felson DT, Anderson JJ, Naimark A, Walker WM, Meenan RF (1988) Obesity and knee osteoarthritis: the Framingham study. Ann Intern Med 109:18–24
12. Hart DJ, Spector TD (1993) The relationship of obesity, fat distribution and osteoarthritis in the general population: the Chingford study. J Rheumatol 20:331–335
13. Van Saase JL, Vandenbroucke JP, Van Romunde LK, Valkenburg HA (1998) Osteoarthritis and obesity in the general population. A relationship calling for an explanation. J Rheumatol 15:1152–1158
14. Magliano M (2008) Obesity and arthritis. Menopause Int 14:149–154
15. Zhang W, Moskowitz RW, Nuki G, Abramson S, Altman RD, Arden N et al (2008) OARSI recommendations for the management of hip and knee osteoarthritis, part II: OARSI evidence-based, expert consensus guidelines. Osteoarthr Cartil 16:137–162
16. Muraki S, Akune T, Oka H, Mabuchi A, En-yo Y, Yoshida M et al (2009) Association of occupational activity with radiographic knee osteoarthritis and lumbar spondylosis in elderly patients of population-based cohorts: a large-scale population-based study. Arthr Rheum 61:779–786
17. Lohmander LS, Gerhardsson de Verdier M, Rollof J, Nilsson PM, Engstrom G (2009) Incidence of severe knee and hip osteoarthritis in relation to different measures of body mass: a population-based prospective cohort study. Ann Rheum Dis 68:490–496
18. Yoshimura N, Muraki S, Oka H, Kawaguchi H, Nakamura K, Akune T (2011) Association of knee osteoarthritis with the accumulation of metabolic risk factors such as overweight, hypertension, dyslipidaemia, and impaired glucose tolerance in Japanese men and women: the ROAD study. J Rheumtol 38:921–930
19. Yoshimura N, Muraki S, Oka H, Tanaka S, Kawaguchi H, Nakamura K, Akune T (2012) Accumulation of metabolic risk factors such as overweight, hypertension, dyslipidaemia, and impaired glucose tolerance raises the risk of occurrence and progression of knee osteoarthritis: a 3-year follow-up of the ROAD study. Osteoarthr Cartil 20:1217–1226
20. De Laet C, Kanis JA, Odén A, Johanson H, Johnell O, Delmas P, Eisman JA, Kroger H, Fujiwara S, Garnero P, McCloskey EV, Mellstrom D, Melton LJ 3rd, Meunier PJ, Pols HA, Reeve J, Silman A, Tenenhouse A (2005) Body mass index as a predictor of fracture risk: a meta-analysis. Osteoporos Int 16:1330–1338
21. Kobayashi T (2011) The relationship between variation in the requirement certification rate in prefectures and nursing care level in long-term care insurance. Otsuma Women's Univ Bull Fac Hum Relat 13:117–128 (in Japanese)
22. Shimitutani S, Inakura N (2007) Japan's public long-term care insurance and the financial condition of insurers: evidence from municipality-level data. Gov Audit Rev 14:27–40
23. Nakamura H (2006) Effect of received condition of long-term care insurance on the regional difference of the certification rate of the disability. J Health Welf Stat 53:1–7 (in Japanese)
24. Yoshimura N, Muraki S, Oka H, Mabuchi A, En-Yo Y, Yoshida M, Saika A, Yoshida H, Suzuki T, Yamamoto S, Ishibashi H, Kawaguchi H, Nakamura K, Akune T (2009) Prevalence of knee osteoarthritis, lumbar spondylosis and osteoporosis in Japanese men and women: the research on osteoarthritis/osteoporosis against disability study. J Bone Miner Metab 27:620–628
25. Orimo H, Hashimoto T, Sakata K, Yoshimura N, Suzuki T, Hosoi T (2000) Trends in the incidence of hip fracture in Japan, 1987–1997: the third nationwide survey. J Bone Miner Metab 18:126–131
26. Yoshimura N, Suzuki T, Hosoi T, Orimo H (2005) Epidemiology of hip fracture in Japan: incidence and risk factors. J Bone Miner Metab 23:78–80
27. Orimo H, Yaegashi Y, Onoda T, Fukushima Y, Hosoi T, Sakata K (2009) Hip fracture incidence in Japan: estimates of new patients in 2007 and 20-year trends. Arch Osteoporos 4:71–77
28. Ueshima H, Ohsaka T, Asakura S (1986) Regional differences in stroke mortality and alcohol consumption in Japan. Stroke 17:19–24

Clin Rheumatol
DOI 10.1007/s10067-014-2687-y

ORIGINAL ARTICLE

Does osteophytosis at the knee predict health-related quality of life decline? A 3-year follow-up of the ROAD study

Shigeyuki Muraki · Toru Akune · Keiji Nagata · Yuyu Ishimoto · Munehito Yoshida · Fumiaki Tokimura · Sakae Tanaka · Hiroshi Kawaguchi · Kozo Nakamura · Hiroyuki Oka · Noriko Yoshimura

Received: 3 February 2014 / Revised: 18 May 2014 / Accepted: 20 May 2014

Abstract The objective of the present longitudinal study was to clarify whether osteophytosis and joint space narrowing predict quality of life (QOL) decline using a longitudinal population-based cohort of the Research on Osteoarthritis/osteoporosis Against Disability (ROAD) study. The present study analyzed 1,525 participants who completed the radiographic examination at baseline and questionnaires regarding QOL at a 3-year follow-up (546 men and 979 women; mean age, 67.0±11.0 years). This study examined the associations of osteophyte area (OPA) and minimum joint space width (mJSW) in the medial compartment of the knee at baseline with pain and physical functional disability measured by the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). OPA and mJSW in the medial compartment of the knee were measured using a knee osteoarthritis (OA) computer-aided diagnosis system. Overall, OPA independently predicted physical functional disability after 3 years of follow-up. When analyzed in men and women separately, OPA, rather than mJSW, was an independent predictor for pain and physical functional disability after 3 years of follow-up in men. OPA, rather than mJSW, also predicted worsening of pain in men during the 3-year follow-up, whereas in women, mJSW, rather than OPA, predicted worsening of pain. In conclusion, the present longitudinal study using a large-scale population from the ROAD study found gender differences in the association of osteophytosis and joint space narrowing with pain and physical functional disability.

Keywords Epidemiology · Longitudinal Studies · Osteoarthritis · Pain · WOMAC

Electronic supplementary material The online version of this article (doi:10.1007/s10067-014-2687-y) contains supplementary material, which is available to authorized users.

S. Muraki (✉) · T. Akune
Department of Clinical Motor System Medicine, 22nd Century Medical & Research Center, Faculty of Medicine, The University of Tokyo, Hongo 7-3-1, Bunkyo-ku, Tokyo 113-8655, Japan
e-mail: murakis-ort@h.u-tokyo.ac.jp

K. Nagata · Y. Ishimoto · M. Yoshida
Department of Orthopaedic Surgery, Wakayama Medical University, Wakayama, Japan

F. Tokimura
Department of Orthopaedic Surgery, Tokyo Metropolitan Geriatric Medical Center, Tokyo, Japan

S. Tanaka · H. Kawaguchi
Department of Orthopaedic Surgery, Faculty of Medicine, The University of Tokyo, Tokyo, Japan

K. Nakamura
National Rehabilitation Center for Persons with Disabilities, Saitama, Japan

H. Oka · N. Yoshimura
Department of Joint Disease Research, 22nd Century Medical & Research Center, Faculty of Medicine, The University of Tokyo, Tokyo, Japan

Introduction

Knee osteoarthritis (OA) is a major public health issue causing chronic pain and disability [1–3]. The prevalence of radiographically confirmed knee OA is high in Japan [4], with 25,300,000 persons aged 40 years and older estimated to experience radiographic knee OA [5]. According to the recent Japanese National Livelihood Survey of the Ministry of Health, Labour and Welfare, osteoarthritis is ranked fourth among diseases that cause disabilities that subsequently require support with activities of daily living [6].

The principal clinical symptoms of knee OA are pain and physical functional disability [7], but the correlation of these symptoms with radiographic severity of knee OA is controversial [4, 8–10]. In terms of disease-specific scales for

Published online: 30 May 2014

estimating pain and physical functional disability due to knee OA, the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) has been used for Caucasians [11] and Asians [12, 13], although these reports were not population-based studies. Furthermore, there is little information on the impact of knee OA on incident pain and physical functional disability using WOMAC in Japan, although reports from a population survey suggest that the disease pattern differs among races [14–16].

Knee OA is characterized by the pathological features of osteophytosis and joint space narrowing, but there is controversy regarding the importance of osteophytes. Nevertheless, hand and hip joint researchers and clinicians have argued that separate radiographic features should be recorded and may be more meaningful than overall composite scores such as the Kellgren-Lawrence (KL) scale [17]. Furthermore, a previous study showed that osteophytes performed better as a primary diagnostic feature than joint space narrowing in cross-sectional knee OA epidemiologic studies [18]. However, most conventional systems for grading radiographic severity have been categorical grades, such as KL grading [19], which is unable to assess osteophytosis and joint space narrowing individually. Several studies have shown that knee OA had a strong effect on quality of life (QOL) [13, 20–22], but in these studies, knee OA was defined by categorical grades such as KL score or American College of Rheumatology grade, total knee arthroplasty, and self-administered questionnaires. In addition, osteophytosis and joint space narrowing were separately evaluated using a radiographic atlas of individual features published by the Osteoarthritis Research Society International in 1995 [23] and revised in 2007 [24]. However, the grading is still limited in reproducibility and sensitivity due to the subjective judgment of individual observers and the categorical classification into four grade scales (0–3). To overcome this problem, osteophyte area (OPA) or joint space width should be evaluated using a fully automatic system [25].

The objective of this study was to clarify whether osteophytosis and joint space narrowing at the knee independently predict decline of QOL measured by WOMAC pain and physical function score during a 3-year follow-up among Japanese men and women using a fully automatic system to measure OPA and joint space width in the longitudinal, population-based cohort from the Research on Osteoarthritis/osteoporosis Against Disability (ROAD) study.

Materials and methods

Study sample The ROAD study is a nationwide prospective study designed to establish epidemiologic indices for the evaluation of clinical evidence to allow for the development of disease-modifying treatments for bone and joint disorders (with OA and osteoporosis as the representative bone and joint diseases). The ROAD study consists of population-based cohorts in several Japanese communities. A detailed profile of the ROAD study has been published previously [4, 5, 26]; therefore, only a brief summary is provided here. To date, the ROAD study has completed the creation of a baseline database including clinical and genetic information for 3,040 inhabitants (1,061 men and 1,979 women) ranging in age from 23 to 95 years (mean, 70.6 years). Participants were recruited from resident registration listings in three communities: an urban region in Itabashi, Tokyo; a mountainous region in Hidakagawa, Wakayama; and a seacoast region in Taiji, Wakayama. All participants provided written informed consent, and the study was conducted with the approval of the ethics committees of the University of Tokyo and the Tokyo Metropolitan Institute of Gerontology. Anthropometric measurements, including height and weight and body mass index (BMI) (weight [kg]/height^2 [m^2]), were calculated. Grip strength was measured on bilateral sides using a TOEI LIGHT handgrip dynamometer (TOEI LIGHT CO., LTD, Saitama, Japan), and the better measurement was used to characterize maximum muscle strength.

Radiographic assessment All participants underwent radiographic examination of both knees using an anterior-posterior view with weight-bearing and foot map positioning by experienced radiological technologists. The beam was positioned parallel to the floor with no angle and aimed at the joint space. We used fluoroscopic guidance with an anterior-posterior X-ray beam to properly visualize the joint space and to centralize the patella over the lower end of the femur. The images were downloaded into Digital Imaging and Communication in Medicine (DICOM) format files. A single experienced orthopedist (S.M.) read the knee radiographs without knowledge of participant clinical status using the KL radiographic atlas for overall knee radiographic grades [19]. Knee OA was defined as KL ≥2. Medial compartment minimum joint space width (mJSW) and medial tibial OPA were measured with the knee osteoarthritis computer-aided diagnosis (KOACAD) system bilaterally. The knee with the least mJSW was defined as the designated knee for each participant. The KOACAD system has been previously described in detail [25, 27, 28]. The KOACAD system is a fully automatic system capable of quantifying the major features of knee OA on standard radiographs. This system allows for objective, accurate, and simple assessment of the structural severity of knee OA in general clinical practice. The KOACAD system was programmed to measure OPA at the medial tibia and mJSW in the medial and lateral compartments using digitized knee radiographs. The KOACAD system was applied to the DICOM data by the experienced orthopedist who developed this system (H.O.), and there is strong reliability for this measurement [25]. Reference values for OPA and mJSW by gender and age strata in Japan using the KOACAD system have been published previously [28]. Lateral OA was defined as being present when a knee had a KL grade ≥2 [19] and lateral joint space narrowing score ≥1 on a 0–3 scale according to the Osteoarthritis Research Society International atlas [24].

Instruments All 3,040 subjects were invited to attend a follow-up interview between 2008 and 2010. We used the WOMAC at the follow-up study to evaluate QOL. The WOMAC is a 24-item OA-specific index consisting of three domains: pain, stiffness, and physical function. Each of these 24 items is graded on either a 5-point Likert scale or a 100-mm visual analog scale [11, 29]. The Likert scale (version LK 3.0) was used in the present study. The domain score ranges from 0 to 20 for pain, 0 to 8 for stiffness, and 0 to 68 for physical function. Japanese versions of the WOMAC have also been validated [30].

Statistical analysis Differences in age, height, weight, BMI, grip strength, OPA, mJSW, and WOMAC scores between men and women were examined using a non-paired student *t* test. The associations of mJSW and OPA with pain and physical functional disability after 3 years were determined by using multiple regression analysis after adjustment for age, BMI, gender, grip strength, and pain score at baseline; after adjustment for age, BMI, gender, grip strength, and physical function score at baseline, respectively, in the overall population; and after adjustment for age, BMI, grip strength, and pain score at baseline and after adjustment for age, BMI, grip strength, and physical function score at baseline, respectively, in men and women. In addition, to determine the independent association of OPA and mJSW with pain and physical function scores, multiple regression analysis was used with age, BMI, gender, grip strength, pain score at baseline, OPA, and mJSW and with age, BMI, gender, grip strength, physical function score at baseline, OPA, and mJSW, respectively, as explanatory variables in the overall population, and with age, BMI, grip strength, pain score at baseline, OPA, and mJSW and with age, BMI, grip strength, physical function score at baseline, OPA, and mJSW, respectively, as explanatory variables in men and women. We classified men and women separately into three groups based on grip strength: <20, ≥20 to <30, and ≥30 and examined the associations of BMI, OPA, and mJSW with pain, using multiple regression analysis with age, BMI, OPA, mJSW, and pain score at baseline as explanatory variables. We also calculated changes of scores as follows: "scores at follow-up−scores at baseline" and determined the association of OPA and mJSW with changes of pain and physical function scores after adjustment for age, BMI, gender, grip strength, and pain score at baseline; after adjustment for age, BMI, gender, grip strength, and physical function score at baseline, respectively, in the overall population; and after adjustment for age, BMI, grip strength, and pain score at baseline and after adjustment for age, BMI, grip strength, and physical function score at baseline, respectively, in men and women. In addition, to determine independent associations of OPA and mJSW with changes of pain and physical function scores, multiple regression analysis was used with age, BMI, gender, grip strength, pain score at baseline, OPA, and mJSW and with age, BMI, gender, grip strength, physical function score at baseline, OPA, and mJSW, respectively, as explanatory variables in the overall population and with age, BMI, grip strength, pain score at baseline, OPA, and mJSW and with age, BMI, grip strength, physical function score at baseline, OPA, and mJSW, respectively, as explanatory variables in men and women. Data analyses were performed using SAS version 9.0 (SAS Institute Inc., Cary, NC).

Results

Of the 3,040 subjects in the baseline study in 2005–2007, 125 had died by the time of the review 3 years later, 123 did not participate in the follow-up study due to bad health, 69 had moved away, 83 declined the invitation to attend the follow-up study, and 155 did not participate in the follow-up study for other reasons. Among the 2,485 subjects who did participate in the follow-up study, we excluded 39 subjects younger than 40 years at baseline. Those participating in the follow-up study were younger than those who did not survive or who did not participate for other reasons (responders 68.6 years, non-responders 75.1 years; $P<0.0001$). The follow-up study participants also were significantly more likely to be women (responders 66.3 % women, non-responders 61.8 % women; $P=0.03$) and were significantly more likely to have knee OA at the baseline examination than either those who did not survive to follow-up or those who did not participate for other reasons (responders 51.5 %, non-responders 60.9 %; $P<0.0001$). Among them, 1,578 subjects provided complete questionnaires of WOMAC both at baseline and follow-up. We excluded 3 subjects who did not undergo plain radiography at the knee and 17 subjects who underwent total knee arthroplasty before the follow-up study. We also excluded 12 subjects whose X-rays were too obscure to measure mJSW and OPA and 21 subjects who had lateral knee OA, leaving a total of 1,525 subjects (546 men and 979 women). The mean duration between baseline and follow-up was 3.3±0.6 years.

Characteristics of the 1,525 participants in the present study are shown in Table 1. BMI was higher in men than women. The prevalence of knee OA was significantly higher in women than men. The OPA was significantly larger and mJSW was significantly narrower in women than men. The WOMAC pain score was similar in men and women, whereas the WOMAC physical function score was worse in women than men, both at baseline and follow-up.

Table 1 Characteristics of subjects

	Overall	Men	Women	*p* value
N	1,525	546	979	
Age (years)	67.0±11.0	68.2±10.7	66.3±11.1	0.001
Height (cm)	155.3±8.8	163.3±6.4	150.8±6.4	<0.0001
Weight (kg)	55.5±10.4	62.2±10.3	51.8±8.5	<0.0001
BMI (kg/m^2)	22.9±3.3	23.3±3.1	22.7±3.3	0.0027
Grip strength (kg)	27.2±9.4	35.4±8.7	22.7±6.4	<0.0001
Knee OA (%)	48.8	38.5	54.5	<0.0001
OPA (mm^2)	3.56±8.43	1.79±5.47	4.54±9.56	<0.0001
mJSW (mm)	2.67±0.94	2.99±0.88	2.50±0.92	<0.0001
WOMAC at baseline				
Pain	1.13±2.20	1.03±2.06	1.18±2.27	0.1753
Physical function	3.05±6.68	2.59±5.74	3.30±7.14	0.0328
WOMAC at follow-up				
Pain	1.82±2.81	1.74±2.69	1.87±2.88	0.3881
Physical function	5.56±9.61	4.79±8.34	5.99±10.22	0.0137

Knee OA was defined as Kellgren-Lawrence grade ≥2 at baseline; except where otherwise indicated, the values at baseline was shown

BMI body mass index, *OA* osteoarthritis, *OPA* osteophyte area, *mJSW* minimum joint space width, *WOMAC* Western Ontario and McMaster Universities Osteoarthritis Index

First, we analyzed the associations of age, BMI, and grip strength with WOMAC pain and physical function scores in men and women (Table 2). Age and grip strength were significantly associated with pain and physical function in men and women, while BMI was significantly associated with pain and physical function in women, but not in men.

Multiple regression analysis after adjustment for age, BMI, grip strength, and pain score at baseline showed that, overall, OPA and mJSW were significant predictors for pain (Table 3). To assess whether OPA and mJSW independently predicted pain, we used multiple regression analysis with age, BMI, grip strength, pain score at baseline, OPA, and mJSW as explanatory variables and found that the association of OPA with pain score after 3 years disappeared, whereas mJSW was an independent predictor for pain after 3 years. When analyzed in men and women, separately, OPA was an independent predictor for pain in men, but mJSW was not. In women, mJSW was an independent predictor for pain, but OPA was not.

In terms of physical function, multiple regression analysis after adjustment for age, BMI, grip strength, and physical function score at baseline showed that OPA and mJSW were significant predictors for physical functional disability (Table 4). To assess whether OPA and mJSW independently predicted physical functional disability, we used multiple regression analysis with age, BMI, grip strength, physical function score at baseline, OPA, and mJSW as explanatory variables and found that OPA and mJSW were independent predictors for physical functional disability. When analyzed in men and women separately, OPA was an independent predictor for physical functional disability in men, but mJSW was not. In women, mJSW was an independent predictor for physical functional disability, but OPA was not.

To clarify the association of OPA, mJSW, and BMI with pain according to muscle strength, men and women were separated into three groups based on grip strength: <20, ≥20 to <30, and ≥30 and the associations of BMI, OPA, and mJSW with pain were examined, using multiple regression analysis with age, BMI, OPA, mJSW, and pain score at baseline as explanatory variables (Supplementary Table 1). In women with grip strength <20, mJSW was significantly associated with pain and BMI tended to be associated with pain, but OPA was not. In men with grip strength <20, BMI, OPA, and mJSW were not significantly associated with pain, likely because only nine men had a grip strength <20. In women with grip strength ≥20 to <30, mJSW and BMI was significantly associated with pain, while OPA was not. In men with grip strength ≥20 to <30, BMI was significantly associated with pain, while OPA and mJSW were not. In men and women with grip strength >30, OPA was significantly associated with pain, while mJSW and BMI were not. We also

Table 2 Effect of age, BMI, and grip strength at baseline on WOMAC pain and physical function scores after 3 years

	Pain		Physical function	
	Regression coefficient (95 % CI)	*P* value	Regression coefficient (95 % CI)	*P* value
Men				
Age (years)	0.05 (0.03 to 0.07)	<0.0001	0.23 (0.17 to 0.29)	<0.0001
BMI (kg/m^2)	0.05 (−0.02 to 0.12)	0.1616	0.17 (−0.06 to 0.39)	0.1459
Grip strength (kg)	−0.05 (−0.07 to −0.02)	0.0003	−0.26 (−0.34 to −0.19)	<0.0001
Women				
Age (years)	0.06 (0.05 to 0.08)	<0.0001	0.33 (0.28 to 0.39)	<0.0001
BMI (kg/m^2)	0.20 (0.14 to 0.25)	<0.0001	0.66 (0.47 to 0.85)	<0.0001
Grip strength (kg)	−0.10 (−0.12 to −0.07)	<0.0001	−0.44 (−0.54 to −0.35)	<0.0001

WOMAC Western Ontario and McMaster Universities Osteoarthritis Index, *CI* confidence interval, *BMI* body mass index

Table 3 Effect of OPA and mJSW at baseline on WOMAC pain scores after 3 years

	Crude regression coefficient[b] (95 % CI)	P value	Adjusted regression coefficient[a] (95 % CI)	*P* value	Adjusted regression coefficient[b] (95 % CI)	*P* value	Standardized beta
Overall							
OPA (mm^2)	0.08 (0.06 to 0.09)	<0.0001	0.02 (0.006 to 0.04)	0.0051	0.01 (−0.003 to 0.03)	0.1036	0.04
mJSW (mm)	−0.76 (−0.90 to −0.61)	<0.0001	−0.30 (−0.44 to −0.16)	<0.0001	−0.26 (−0.41 to −0.12)	0.0005	−0.09
Men							
OPA (mm^2)	0.09 (0.04 to 0.13)	<0.0001	0.05 (0.01 to 0.08)	0.0078	0.05 (0.01 to 0.09)	0.0127	0.1
mJSW (mm)	−0.45 (−0.71 to −0.20)	0.0005	−0.11 (−0.33 to 0.12)	0.3466	0.02 (−0.22 to 0.27)	0.8574	0.007
Women							
OPA (mm^2)	0.08 (0.06 to 0.09)	<0.0001	0.02 (−0.0008 to 0.03)	0.0623	0.006 (−0.01 to 0.02)	0.4789	0.02
mJSW (mm)	−0.96 (−1.15 to −0.78)	<0.0001	−0.41 (−0.58 to −0.23)	<0.0001	−0.39 (−0.57 to −0.20)	<0.0001	−0.12

WOMAC Western Ontario and McMaster Universities Osteoarthritis Index, *CI* confidence interval, *OPA* osteophyte area, *mJSW* minimum joint space width

[a] Adjusted regression coefficients for pain scores were calculated by multiple regression analysis after adjustment for age, BMI, gender, grip strength, and pain score at baseline in the overall population and after adjustment for age, BMI, grip strength, and pain score at baseline in men and women

[b] Adjusted regression coefficients for pain scores were calculated by multiple regression analysis with age, BMI, gender, grip strength, pain score at baseline, OPA, and mJSW as explanatory variables in the overall population and with age, BMI, grip strength, pain score at baseline, OPA, and mJSW as explanatory variables in men and women

examined the association of OPA, mJSW, and BMI with physical function disability according to muscle strength (Supplementary Table 2). Results were similar to findings for pain.

To examine whether OPA and mJSW predicted worsening of pain during the 3-year follow-up, we calculated differences of the WOMAC pain scores between baseline and follow-up (Table 5). In the overall population, mJSW was a significant predictor for worsening of pain after adjustment for age, BMI, gender, and pain score at baseline, whereas OPA was not. When analyzed in men and women separately, OPA was a significant predictor for worsening of pain in men, whereas mJSW was a significant predictor for worsening of pain in women.

We also examined whether OPA and mJSW predicted worsening of physical functional disability during the 3-year follow-up (Table 6). In the overall population, OPA and mJSW were significant predictors for worsening of physical functional disability after adjustment for age, BMI, gender, grip strength, and physical function score at baseline. To

Table 4 Effect of OPA and mJSW at baseline on WOMAC physical function scores after 3 years

	Crude regression coefficient[b] (95 % CI)	*P* value	Adjusted regression coefficient[a] (95 % CI)	*P* value	Adjusted regression coefficient[b] (95 % CI)	*P* value	Standardized beta
Overall							
OPA (mm^2)	0.34 (0.29 to 0.40)	<0.0001	0.09 (0.04 to 0.14)	0.0002	0.05 (0.0004 to 0.10)	0.0480	0.04
mJSW (mm)	−3.24 (−3.73 to −2.75)	<0.0001	−1.36 (−1.80 to −0.92)	<0.0001	−1.22 (−1.68 to −0.76)	<0.0001	−0.12
Men							
OPA (mm^2)	0.35 (0.23 to 0.48)	<0.0001	0.19 (0.08 to 0.30)	0.0008	0.14 (0.02 to 0.26)	0.0204	0.09
mJSW (mm)	−2.21 (−2.99 to −1.44)	<0.0001	−1.07 (−1.77 to −0.37)	0.0027	−0.69 (−1.46 to 0.07)	0.0758	−0.07
Women							
OPA (mm^2)	0.34 (0.27 to 0.40)	<0.0001	0.06 (0.009 to 0.12)	0.0225	0.03 (−0.03 to 0.08)	0.3305	0.03
mJSW (mm)	−3.86 (−4.51 to −3.20)	<0.0001	−1.49 (−2.05 to −0.92)	<0.0001	−1.41 (−2.00 to −0.82)	<0.0001	−0.13

WOMAC Western Ontario and McMaster Universities Osteoarthritis Index, *CI* confidence interval, *OPA* osteophyte area, *mJSW* minimum joint space width

[a] Adjusted regression coefficients for physical function score were calculated by multiple regression analysis after adjustment for age, BMI, gender, grip strength, and physical function score at baseline in the overall population and after adjustment for age, BMI, grip strength, and physical function score at baseline in men and women

[b] Adjusted regression coefficients for physical function score were calculated by multiple regression analysis with age, BMI, gender, grip strength, physical function score at baseline, OPA, and mJSW as explanatory variables in the overall population and with age, BMI, grip strength, physical function score at baseline, OPA, and mJSW as explanatory variables in men and women

examine whether OPA and mJSW independently predicted worsening of physical functional disability, we used multiple regression analysis with age, BMI, gender, grip strength, physical function score at baseline, OPA, and mJSW as explanatory variables and found that mJSW was an independent predictor for worsening of physical functional disability, but the significant association of OPA disappeared. When analyzed in men and women separately, after adjustment for age, BMI, grip strength, and physical function scores at baseline, OPA and mJSW were significant predictors for worsening of physical functional disability in men; in women, mJSW was a significant predictor for worsening of physical functional disability, but OPA was not. To examine whether OPA and mJSW independently predicted worsening of physical functional disability in men, we used multiple regression analysis with age, BMI, grip strength, physical function score at baseline, OPA, and mJSW as explanatory variables and found that the significant association of OPA and mJSW with worsening in physical function disappeared.

Discussion

This is the first large-scale study to examine whether osteophytosis and joint space narrowing independently predict QOL decline measured by WOMAC pain and physical function score in a longitudinal model. In addition, osteophytosis and joint space narrowing were estimated not by categorical grade but by continuous values such as OPA and mJSW at the knee. In the present study, OPA, rather than mJSW, was an independent predictor for pain and physical functional disability after 3 years of follow-up in men. OPA, rather than mJSW, also predicted worsening of pain in men during the 3-year follow-up, whereas mJSW, rather than OPA, predicted worsening of pain in women.

Previous studies have shown that knee OA has a strong effect on QOL [13, 20–22]; however, the knee OA was defined by KL grade or other categorical methods. KL grade is the most conventional system to grade radiographic severity of knee OA, but in this categorical system, osteophyte formation and joint space narrowing are not assessed separately. Thus, we cannot clarify whether osteophytosis and joint space narrowing have distinct effects on QOL. In addition, our previous cross-sectional study showed that osteophytosis was not strongly related to joint space narrowing on plain radiographs [31]. Furthermore, our experimental mouse model for OA identified a cartilage-specific molecule, carminerin, that regulates osteophytosis without affecting joint cartilage destruction during OA progression [32, 33]. This accumulating evidence indicates that osteophytosis and joint space narrowing may have distinct etiologic mechanisms and their progression may be neither constant nor proportional. Thus, to examine factors associated with knee OA, these two OA features should be assessed separately. Furthermore, because categorical methods are statistically less powerful than continuous methods, the association between knee OA and QOL might have been underestimated in previous studies. In addition, most studies regarding the association of knee OA with QOL were cross-sectional designs; thus, a causal relationship could not be clarified. So far, the role of the osteophytes in OA is controversial, with several researchers believing that osteophytes are merely a reflection of age and not associated with any of the clinical symptoms of OA, though few reported data support or refute this argument. This study was the first longitudinal model to report that osteophytosis, rather than mJSW, predicted QOL decline in men.

Table 5 Effect of OPA and mJSW at baseline on worsening of WOMAC pain scores after 3 years

	Crude regression coefficient[a] (95 % CI)	*P* value	Adjusted regression coefficient (95 % CI)	*P* value
Overall				
OPA (mm^2)	0.01 (−0.004 to 0.03)	0.1443	–	–
mJSW (mm)	−0.16 (−0.29 to −0.03)	0.0132	−0.30 (−0.44 to −0.16)	<0.0001
Men				
OPA (mm^2)	0.04 (0.006 to 0.08)	0.0209	0.05 (0.01 to 0.08)	0.0078
mJSW (mm)	−0.06 (−0.28 to 0.15)	0.5684	–	–
Women				
OPA (mm^2)	0.006 (−0.01 to 0.02)	0.4880	–	–
mJSW (mm)	−0.24 (−0.41 to −0.07)	0.006	−0.41 (−0.58 to −0.23)	<0.0001

WOMAC Western Ontario and McMaster Universities Osteoarthritis Index, *CI* confidence interval, *OPA* osteophyte area, *mJSW* minimum joint space width

[a] Adjusted regression coefficients for change of scores were calculated by multiple regression analysis after adjustment for age, BMI, gender, grip strength, and pain score at baseline in the overall population and after adjustment for age, BMI, grip strength, and pain score at baseline in men and women

Table 6 Effect of OPA and mJSW at baseline on worsening of WOMAC physical function scores after 3 years

	Crude regression coefficient[b] (95 % CI)	P value	Adjusted regression coefficient[a] (95 % CI)	P value	Adjusted regression coefficient[b] (95 % CI)	P value	Standardized beta
Overall							
OPA (mm^2)	0.10 (0.05 to 0.14)	<0.0001	0.05 (0.002 to 0.10)	0.0393	0.01 (−0.04 to 0.06)	0.6078	0.01
mJSW (mm)	−1.44 (−1.84 to −1.04)	<0.0001	−1.14 (−1.58 to −0.69)	<0.0001	−1.10 (−1.57 to −0.63)	<0.0001	−0.14
Men							
OPA (mm^2)	0.18 (0.07 to 0.29)	0.0012	0.14 (0.03 to 0.26)	0.012	0.10 (−0.02 to 0.23)	0.1095	0.08
mJSW (mm)	−1.27 (−1.95 to 0.59)	0.0003	−0.93 (−1.65 to −0.21)	0.0113	−0.66 (−1.45 to 0.13)	0.1021	−0.08
Women							
OPA (mm^2)	0.08 (0.03 to 0.13)	0.0024	0.03 (−0.02 to 0.09)	0.2521	–	–	–
mJSW (mm)	−1.58 (−2.10 to −1.05)	<0.0001	−1.25 (−1.82 to −0.68)	<0.0001	–	–	

WOMAC Western Ontario and McMaster Universities Osteoarthritis Index, *CI* confidence interval, *OPA* osteophyte area, *mJSW* minimum joint space width

[a] Adjusted regression coefficients for changes in physical function scores were calculated by multiple regression analysis after adjustment for age, BMI, gender, grip strength, and physical function score at baseline overall and after adjustment for age, BMI, grip strength, and physical function score at baseline in men and women

[b] Adjusted regression coefficients for changes in physical function scores were calculated by multiple regression analysis with age, BMI, gender, grip strength, OPA, mJSW, and physical function score at baseline as overall explanatory variables and with age, BMI, grip strength, OPA, mJSW, and physical function score at baseline as explanatory variables in men

The association of osteophytosis with QOL may be complex. Osteophytes may not have any primary effect themselves but rather serve as markers for factors that strongly affect QOL decline. First, osteophytosis appears to start from activation of periosteal layers, with initial generation of chondrophytes and subsequent calcification to real osteophytes. The process is probably an adaptive reaction of the joint to cope with joint instability, and thus, OPA may indicate the severity of joint instability [34], which might lead to pain and physical functional disability, particularly in men. In addition, it is possible that osteophytosis is strongly associated with patellofemoral disease [35], which is associated with knee pain [36]. This is an area where further research would be useful. Nevertheless, our results indicate that the presence or absence of osteophytosis, rather than joint space narrowing, is an appropriate method to predict QOL decline in men.

The present study revealed gender differences in the associations of osteophytosis and joint space narrowing with pain and physical functional disability. Joint space narrowing was an independent predictor for QOL decline measured by WOMAC pain and physical function scores in women, but not in men. Our previous cross-sectional study also showed that the odds ratio of knee pain for KL grade 3 or 4 knee OA was approximately twice as high in women as in men [4]. Considering the definition of KL grade [19], this finding may indicate that joint space narrowing is more strongly associated with pain in women than men. At the same time, osteophytosis is an independent predictor for QOL decline measured by the WOMAC pain and physical function scores in men, but not in women. As mentioned above, osteophytosis may represent joint instability or patellofemoral disease, which may be more strongly associated with pain and physical function than joint space narrowing due to cartilage loss in men. These findings may be partly explained by the lower muscle mass in women compared with men. Previous reports have shown that muscle mass is also associated with QOL [37, 38]. BMI also has different effect on QOL between men and women. To clarify the effect of muscle strength on the association of OPA, mJSW, and BMI with QOL, we classified subjects according to grip strength and examined the association of OPA, mJSW, and BMI with WOMAC pain score. In both men and women with strong muscle strength, OPA was associated with pain rather than mJSW or BMI, whereas in those with weaker muscle strength, mJSW and BMI were associated with pain rather than OPA. We also examined the association of OPA, mJSW, and BMI with WOMAC physical function score according to grip strength, and results were similar to those for pain. This means that muscle strength, rather than gender itself, may affect differences between men and women in the association of mJSW and OPA with QOL.

There is a limitation in the present study. We did not include other weight-bearing joints that can have OA, such as hip OA, in the analysis, although such disorders may also affect QOL decline. However, the prevalence of KL grade 3 or 4 hip OA is 1.4 and 3.5 % in Japanese men and women [39], respectively, which is much less than the prevalence of KL grade 3 or 4 knee OA (13.5 and 24.6 % in Japanese men and women, respectively) [4]. Thus, it is possible that hip OA would not strongly affect the results of the present study.

In conclusion, the present longitudinal study using a large-scale population from the ROAD study revealed that osteophytosis is a predictor for QOL decline in men. We also revealed gender differences in the association of osteophytosis and joint space narrowing with QOL decline. Future studies, along with longitudinal surveys in the ROAD study, will help further the understanding of osteophytosis and joint space narrowing mechanisms at the knee and their relationship with QOL.

Acknowledgments The authors wish to thank Dr. Seizo Yamamoto, Hideaki Ishibashi, Yorito Anamizu, and the other members of the Department of Orthopedics at Tokyo Metropolitan Geriatric Medical Center; Mr. Kutsuma and the other members of the Department of Radiology at Tokyo Metropolitan Geriatric Medical Center; Mrs. Tomoko Takijiri and the other members of the Public Office in Hidakagawa Town; and Mrs. Tamako Tsutsumi, Mrs. Kanami Maeda, and the other members of the Public Office in Taiji Town, for their assistance in locating and scheduling participants for examinations.

Funding This work was supported by Grants-in-Aid for Scientific Research (S19109007, B20390182, C20591737, C20591774), for Young Scientists (A18689031), and for Exploratory Research (19659305) from the Japanese Ministry of Education, Culture, Sports, Science and Technology; grants (H17-Men-eki-009, H18-Choujyu-037, H20-Choujyu-009, H21-Chouju-Wakate-011, and H22-Chouju-Wakate-007) from the Ministry of Health, Labor and Welfare, a Research Aid from the Japanese Orthopaedic Association (JOA-Subsidized Science Project Research 2006–1) and Grant No. 166 from the Japan Orthopaedics and Traumatology Foundation are also acknowledged.

Disclosures All authors have no conflicts of interest to state.

References

1. Sharma L, Kapoor D (2007) Epidemiology of osteoarthritis. In: Moskowitz RW, Altman RD, Hochberg MC, Buckwalter JA, Goldberg VM (eds) Osteoarthritis diagnosis and medical/surgical management, 4th edn. Lippincott Williams & Wilkins, Philadelphia, pp 3–26
2. Guccione AA, Felson DT, Anderson JJ, Anthony JM, Zhang Y, Wilson PW, Kelly-Hayes M, Wolf PA, Kreger BE, Kannel WB (1994) The effects of specific medical conditions on the functional limitations of elders in the Framingham Study. Am J Public Health 84:351–358
3. Felson DT, Zhang Y (1998) An update on the epidemiology of knee and hip osteoarthritis with a view to prevention. Arthritis Rheum 41: 1343–1355
4. Muraki S, Oka H, Akune T, Mabuchi A, En-yo Y, Yoshida M, Saika A, Suzuki T, Yoshida H, Ishibashi H, Yamamoto S, Nakamura K, Kawaguchi H, Yoshimura N (2009) Prevalence of radiographic knee osteoarthritis and its association with knee pain in the elderly of Japanese population-based cohorts: the ROAD study. Osteoarthr Cartil 17:1137–1143
5. Yoshimura N, Muraki S, Oka H, Mabuchi A, En-Yo Y, Yoshida M, Saika A, Yoshida H, Suzuki T, Yamamoto S, Ishibashi H, Kawaguchi H, Nakamura K, Akune T (2009) Prevalence of knee osteoarthritis, lumbar spondylosis and osteoporosis in Japanese men and women: the Research on Osteoarthritis/osteoporosis Against Disability (ROAD). J Bone Miner Metab 27:620–628
6. Ministry of Health, Labour and Welfare. The outline of the results of National Livelihood Survey (2007) Available at http://www.mhlw.go.jp/toukei/list/20-19-1.html
7. Linaker CH, Walker-Bone K, Palmer K, Cooper C (1999) Frequency and impact of regional musculoskeletal disorders. Baillieres Clin Rheumatol 13:197–215
8. Duncan R, Peat G, Thomas E, Hay E, McCall I, Croft P (2007) Symptoms and radiographic osteoarthritis: not as discordant as they are made out to be? Ann Rheum Dis 66:86–91
9. Hannan MT, Felson DT, Pincus T (2000) Analysis of the discordance between radiographic changes and knee pain in osteoarthritis of the knee. J Rheumatol 27:1513–1517
10. Neogi T, Felson D, Niu J, Nevitt M, Lewis CE, Aliabadi P, Sack B, Torner J, Bradley L, Zhang Y (2009) Association between radiographic features of knee osteoarthritis and pain: results from two cohort studies. BMJ 339:b2844
11. Bellamy N, Buchanan WW, Goldsmith CH, Campbell J, Stitt LW (1988) Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. J Rheumatol 15:1833–1840
12. Thumboo J, Chew LH, Soh CH (2001) Validation of the Western Ontario and McMaster University osteoarthritis index in Asians with osteoarthritis in Singapore. Osteoarthr Cartil 9:440–446
13. Woo J, Lau E, Lee P, Kwok T, Lau WC, Chan C, Chiu P, Li E, Sham A, Lam D (2004) Impact of osteoarthritis on quality of life in a Hong Kong Chinese population. J Rheumatol 31:2433–2438
14. Dillon CF, Rasch EK, Gu Q, Hirsch R (2006) Prevalence of knee osteoarthritis in the United States: arthritis data from the Third National Health and Nutrition Examination Survey 1991–94. J Rheumatol 33:2271–2279
15. Jordan JM, Helmick CG, Renner JB, Luta G, Dragomir AD, Woodard J, Fang F, Schwartz TA, Abbate LM, Callahan LF, Kalsbeek WD, Hochberg MC (2007) Prevalence of knee symptoms and radiographic and symptomatic knee osteoarthritis in African Americans and Caucasians: the Johnston County Osteoarthritis Project. J Rheumatol 34:172–180
16. Yoshida S, Aoyagi K, Felson DT, Aliabadi P, Shindo H, Takemoto T (2002) Comparison of the prevalence of radiographic osteoarthritis of the knee and hand between Japan and the United States. J Rheumatol 29:1454–1458
17. Croft P, Cooper C, Wickham C, Coggon D (1990) Defining osteoarthritis of the hip for epidemiologic studies. Am J Epidemiol 132:514–522
18. Spector TD, Hart DJ, Byrne J, Harris PA, Dacre JE, Doyle DV (1993) Definition of osteoarthritis of the knee for epidemiologic studies. Ann Rheum Dis 52:790–794
19. Kellgren JH, Lawrence JS (eds) (1963) The epidemiology of chronic rheumatism: atlas of standard radiographs of arthritis. Blackwell Scientific, Oxford
20. Brazier JE, Harper R, Munro J, Walters SJ, Snaith ML (1999) Generic and condition-specific outcome measures for people with osteoarthritis of the knee. Rheumatology (Oxford) 38:870–877
21. Hill CL, Parsons J, Taylor A, Leach G (1999) Health related quality of life in a population sample with arthritis. J Rheumatol 26: 2029–2035
22. Muraki S, Akune T, Oka H, En-yo Y, Yoshida M, Saika A, Suzuki T, Yoshida H, Ishibashi H, Tokimura F, Yamamoto S, Nakamura K, Kawaguchi H, Yoshimura N (2010) Association of radiographic and symptomatic knee osteoarthritis with health-related quality of life in a population-based cohort study in Japan: the ROAD study. Osteoarthr Cartil 18:1227–1234
23. Altman RD, Hochberg M, Murphy WA Jr, Wolfe F, Lequesne M (1995) Atlas of individual radiographic features in osteoarthritis. Osteoarthr Cartil 3(Suppl A):3–70
24. Altman RD, Gold GE (2007) Atlas of individual radiographic features in osteoarthritis, revised. Osteoarthr Cartil 15(Suppl A):A1–A56
25. Oka H, Muraki S, Akune T, Mabuchi A, Suzuki T, Yoshida H, Yamamoto S, Nakamura K, Yoshimura N, Kawaguchi H (2008)

Fully automatic quantification of knee osteoarthritis severity on plain radiographs. Osteoarthr Cartil 16:1300–1306
26. Yoshimura N, Muraki S, Oka H, Kawaguchi H, Nakamura K, Akune T (2010) Cohort profile: research on osteoarthritis/osteoporosis against disability study. Int J Epidemiol 39:988–995
27. Muraki S, Oka H, Akune T, En-yo Y, Yoshida M, Nakamura K, Kawaguchi H, Yoshimura N (2011) Association of occupational activity with joint space narrowing and osteophytosis in the medial compartment of the knee: the ROAD study. Osteoarthr Cartil 19:840–846
28. Oka H, Muraki S, Akune T, Nakamura K, Kawaguchi H, Yoshimura N (2010) Normal and threshold values of joint space width, joint space area, osteophyte area and fibro-tibial angle using a computer-assisted measuring system (KOACAD) to evaluate knee osteoarthritis: The ROAD study. J Orthop Sci 15:781–789
29. Barr S, Bellamy N, Buchanan WW, Chalmers A, Ford PM, Kean WF, Kraag GR, Gerecz-Simon E, Campbell J (1994) A comparative study of signal versus aggregate methods of outcome measurement based on the WOMAC Osteoarthritis Index. J Rheumatol 21:2106–2112
30. Hashimoto H, Hanyu T, Sledge CB, Lingard EA (2003) Validation of a Japanese patient-derived outcome scale for assessing total knee arthroplasty: comparison with Western Ontario and McMaster Universities osteoarthritis index (WOMAC). J Orthop Sci 8:288–293
31. Muraki S, Oka H, Akune T, En-yo Y, Yoshida M, Suzuki T, Yoshida H, Ishibashi H, Tokimura F, Yamamoto S, Nakamura K, Kawaguchi H, Yoshimura N (2011) Independent association of joint space narrowing and osteophyte formation at the knee with health-related quality of life in Japan: a cross-sectional study. Arthritis Rheum 63:3859–3864
32. Yamada T, Kawano H, Koshizuka Y, Fukuda T, Yoshimura K, Kamekura S, Saito T, Ikeda T, Kawasaki Y, Azuma Y, Ikegawa S, Hoshi K, Chung UI, Nakamura K, Kato S, Kawaguchi H (2006) Carminerin contributes to chondrocyte calcification during endochondral ossification. Nat Med 12:665–670
33. Kamekura S, Kawasaki Y, Hoshi K, Shimoaka T, Chikuda H, Maruyama Z, Komori T, Sato S, Takeda S, Karsenty G, Nakamura K, Chung UI, Kawaguchi H (2006) Contribution of runt-related transcription factor 2 to the pathogenesis of osteoarthritis in mice after induction of knee joint instability. Arthritis Rheum 54:2462–2470
34. van denBerg WB (1999) Osteophyte formation in osteoarthritis. Osteoarthr Cartil 7:333
35. Kijowski R, Blankenbaker D, Stanton P, Fine J, De Smet A (2006) Correlation between radiographic findings of osteoarthritis and arthroscopic findings of articular cartilage degeneration within the patellofemoral joint. Skelet Radiol 35:895–902
36. Chang CB, Han I, Kim SJ, Seong SC, Kim TK (2007) Association between radiological findings and symptoms at the patellofemoral joint in advanced knee osteoarthritis. J Bone Joint Surg (Br) 89:1324–1328
37. Iannuzzi-Sucich M, Prestwood KM, Kenny AM (2002) Prevalence of sarcopenia and predictors of skeletal muscle mass in healthy, older men and women. J Gerontol A Biol Sci Med Sci 57:M772–M777
38. Sayer AA, Syddall HE, Martin HJ, Dennison EM, Roberts HC, Cooper C (2006) Is grip strength associated with health-related quality of life? Findings from the Hertfordshire Cohort Study. Age Ageing 35:409–415
39. Inoue K, Wicart P, Kawasaki T, Huang J, Ushiyama T, Hukuda S, Courpied J (2000) Prevalence of hip osteoarthritis and acetabular dysplasia in French and Japanese adults. Rheumatology (Oxford) 39:745–748

Osteoporos Int (2015) 26:151–161
DOI 10.1007/s00198-014-2844-9

ORIGINAL ARTICLE

Serum levels of 25-hydroxyvitamin D and the occurrence of musculoskeletal diseases: a 3-year follow-up to the road study

N. Yoshimura · S. Muraki · H. Oka · K. Nakamura · H. Kawaguchi · S. Tanaka · T. Akune

Received: 7 March 2014 / Accepted: 6 August 2014 / Published online: 20 August 2014

Abstract

Summary Assessment of serum 25-hydroxyvitamin D levels in association with the occurrence of musculoskeletal diseases using a population-based cohort study design revealed that serum 25-hydroxyvitamin D levels could predict the occurrence of osteoporosis at the femoral neck within 3 years, but not the occurrence of knee osteoarthritis or lumbar spondylosis.

Introduction The aim of this study is to clarify the association between serum 25-hydroxyvitamin D (25D) levels and occurrence of osteoporosis and osteoarthritis in the general population.

Methods The Research on Osteoarthritis/Osteoporosis Against Disability study, a large-scale population-based cohort study, was performed during 2005–2007. Serum 25D levels were measured in 1,683 participants. Of these, 1,384 individuals (81.9 %) completed a second follow-up survey 3 years later. Osteoporosis was defined according to World Health Organization criteria, in which osteoporosis is diagnosed by T-scores of bone mineral density (BMD) that are 2.5 standard deviations (SD) less than normal BMD. Knee osteoarthritis and lumbar spondylosis were defined as Kellgren–Lawrence grade ≥2, using paired X-ray films. Cumulative incidences were determined according to changes in measurements using World Health Organization criteria for osteoporosis or Kellgren–Lawrence grades for osteoarthritis between the baseline and second survey.

Results The mean (SD) serum 25D level of the 1,384 participants in both surveys was 23.4 ng/mL (6.5). The annual cumulative incidences of osteoporosis at L2–4 and the femoral neck were 0.76 and 1.83 %/year, respectively. The incidences of knee osteoarthritis and lumbar spondylosis were 3.3 and 11.4 %/year, respectively. After adjusting for potential associated factors, logistic regression analyses revealed that the odds ratio for the occurrence of femoral neck osteoporosis significantly decreased as serum 25D levels increased (+1 SD; odds ratio 0.67; 95 % confidence interval 0.49–0.92; $p=0.014$).

Conclusions Higher serum 25D levels may prevent the occurrence of osteoporosis at the femoral neck, but not knee osteoarthritis, lumbar spondylosis, or osteoporosis at L2–4.

Keywords 25-Hydroxyvitamin D · Epidemiology · Incidence · Osteoarthritis · Osteoporosis · Population-based cohort study

N. Yoshimura (✉) · H. Oka
Department of Joint Disease Research, 22nd Century Medical and Research Center, Graduate School of Medicine, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8655, Japan
e-mail: YOSHIMURAN-ORT@h.u-tokyo.ac.jp

S. Muraki
Department of Clinical Motor System Medicine, 22nd Century Medical and Research Center, Graduate School of Medicine, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8655, Japan

K. Nakamura · T. Akune
National Rehabilitation Center for Persons with Disabilities, 1, Namiki 4-chome, Tokorozawa City, Saitama Prefecture 359-8555, Japan

H. Kawaguchi
JCHO Tokyo Shinjuku Medical Center, 5-1, Tsukudo-cho, Shinjyuku-ku, Tokyo 162-8542, Japan

S. Tanaka
Department of Orthopaedic Surgery, Faculty of Medicine, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8655, Japan

Introduction

As the average age of the human population is rapidly increasing, the development of methods to prevent musculoskeletal disorders that impair activities of daily life (ADLs) and quality of life (QOL) in the elderly has become an urgent need. Osteoporosis and osteoarthritis are major bone and joint health problems that cause impairment of ADL and QOL among the elderly and lead to increased morbidity and mortality in this population. The recent National Livelihood Survey performed by the Ministry of Health, Labour and Welfare in Japan [1] found that arthritis is ranked fourth, and falls and osteoporotic fractures are fifth among the diseases that cause disabilities requiring support and long-term care. Therefore, developing approaches to prevent osteoporosis and osteoarthritis could reduce the impairment of ADL and QOL and subsequent disabilities among the elderly.

Vitamin D influences bone quality and is important in maintaining bone density [2, 3]. A number of studies have reported an association between inadequate vitamin D intake and osteoporosis [4–7]. In contrast, no clear association has been found between vitamin D and osteoarthritis. An association between low levels of 25-hydroxyvitamin D (25D) and prevalent hip osteoarthritis was observed in cross-sectional studies [8, 9]. In addition, it has been shown that low serum 25D levels increased the risk of knee osteoarthritis progression [10] and incident hip joint space narrowing [11]. However, it has also been reported that serum 25D levels did not predict joint space narrowing or loss of cartilage volume of the knee [12] or clinically diagnosed knee or hip osteoarthritis [13].

In the present study, we performed a population-based cohort survey using the Research on Osteoarthritis/Osteoporosis Against Disability (ROAD) study cohorts. The second ROAD survey, a 3-year follow-up survey that repeated the baseline examinations performed in the original ROAD study, has been completed. The aim of our study was to determine whether vitamin D inadequacy affects the occurrence of musculoskeletal diseases, including osteoporosis, knee osteoarthritis, and lumbar spondylosis.

Methods

Study participants

The present study was performed using the ROAD study cohorts established in 2005. The ROAD study is a national, prospective study of osteoarthritis that is made up of population-based cohorts from several communities in Japan. Details of the cohort profile have been reported elsewhere [14, 15]. In brief, between 2005 and 2007, a baseline database was created that included clinical and genetic information for 3,040 residents (1,061 men, 1,979 women; mean age, 70.3 years (SD 11.0), 71.0 years (10.7) in men, 69.9 years (11.2) in women) of Japan. The subjects were recruited from resident registration listings in three communities with different characteristics: 1,350 subjects from an urban region in Itabashi, Tokyo; 864 subjects from a mountainous region in Hidakagawa, Wakayama; and 826 subjects from a coastal region in Taiji, Wakayama. In the present study, we enrolled all 1,690 subjects (596 men, 1,094 women; mean age 65.2 years (12.0), 66.3 years (11.7) in men, 64.7 years (12.1) in women) from the mountainous and coastal regions who participated in the ROAD study. Bone mineral density (BMD) measurements and blood and urinary examinations were performed on the participants from the mountainous region and the coastal region.

The study participants provided written informed consent. The study was conducted with the approval of the ethics committees of the University of Tokyo (no. 1264 and no. 1326) and the University of Wakayama Medical University (no. 373).

Baseline assessment

Interviewer-administered questionnaire

Participants completed an interviewer-administered questionnaire that consisted of questions related to lifestyle, including occupation, smoking habits, alcohol consumption, family history, medical history, physical activity, reproductive history, and health-related QOL.

Dietary assessment

A brief diet history questionnaire (BDHQ) was administered to assess the diet of the participants, and nutrient intakes from the preceding month were determined. The BDHQ is a four-page structured questionnaire that includes questions about the frequency of consumption of 80 principal foods. The serving sizes of the foods are described as normal portions that are the standard weight and volume of servings commonly consumed by the general Japanese population. The BDHQ was modified from a comprehensive, 16-page validated self-administered diet history questionnaire [16]. A total of 141 variables, including dietary energy and nutrient intakes, were calculated using an ad hoc computer algorithm for the BDHQ. Detailed explanations accompanied each questionnaire. Well-trained interviewers clarified any unclear sections of the questionnaire, which was completed by the participants at their leisure.

Anthropometric measurements and medical history

Anthropometric measurements, including height and weight, were measured in all participants. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. Handgrip strength was measured using a Toei Light handgrip dynamometer (Toei Light Co., Ltd., Saitama, Japan). Both hands were tested and the larger value used to determine the maximum muscle strength of the subject. Experienced orthopedic surgeons collected medical information about pain, swelling, and range of motion of the knee.

Blood and urinary examinations

Samples were collected between the end of October and the middle of January from participants in the mountainous and coastal areas. All blood and urine samples were extracted between 09:00 and 15:00. After blood samples were centrifuged, the sera and urine samples were immediately placed on dry ice and transferred to a deep freezer within 24 h. Samples were stored at −80 °C until assayed.

Serum levels of 25D were measured using a radioimmunoassay with a ^{125}I-labeled tracer (DiaSorin, Stillwater, MN, USA) [17]. Intact parathyroid hormone (iPTH) levels were measured using an electrochemiluminescence immunoassay (Roche Diagnostics GmbH, Manheim, Germany). Serum N-terminal propeptide of type I procollagen (PINP), a marker of bone formation, was measured using a radioimmunoassay (Orion Diagnostics, Espoo, Finland). Urinary levels of β-isomerized C-terminal telopeptide cross-links of type I collagen (β-CTX), a marker of bone resorption, were determined using an enzyme-linked immunosorbent assay (Fujirebio, Inc., Tokyo, Japan). Urinary β-CTX values were standardized to urinary creatinine concentrations.

BMD examination

Lumbar spine and proximal femur BMD values were determined using dual-energy X-ray absorptiometry (DXA; Hologic Discovery; Hologic, Waltham, MA, USA)

X-ray examination

Plain radiographs of the lumbar spine in the anteroposterior and lateral views and both knees in the anteroposterior view with weight bearing and foot map positioning were obtained.

Three-year follow-up

Between 2008 and 2010, the 1,690 participants were invited to participate in the 3-year follow-up of the ROAD survey, which repeated the baseline examinations.

Definition of osteoporosis and osteoarthritis

Osteoporosis was defined according to World Health Organization criteria; osteoporosis was diagnosed when BMD T-scores were lower than peak bone mass by 2.5 standard deviations (SD) [18]. The mean (SD) for the L2–4 BMD in young adult men and women, as measured by the Hologic DXA in Japan, is 1.011 g/cm^2 (0.119) [19]. Therefore, osteoporosis of the lumbar spine was defined as an L2–4 BMD <0.714 g/cm^2. The mean (SD) BMDs of the femoral neck in young adult men and women are 0.863 g/cm^2 (0.127) and 0.787 g/cm^2 (0.109), respectively [19]. Therefore, osteoporosis at the femoral neck in men and women was defined as a femoral neck BMD <0.546 and <0.515 g/cm^2, respectively.

Knee and lumbar radiographs were read by a single experienced orthopedist who was blinded to participants' clinical status and were categorized using the Kellgren–Lawrence grading scale [20]: grade 0, normal; grade 1, slight osteophytes; grade 2, definite osteophytes; grade 3, disk space narrowing with large osteophytes; and grade 4, bone sclerosis, disk space narrowing, and large osteophytes. In the present study, a subject with at least one knee and at least one lumbar spine with a Kellgren–Lawrence grade ≥2 was defined as having radiographic knee osteoarthritis and lumbar spondylosis, respectively. When a different grade was assigned to each knee, the participant was classified to the higher grade. To examine intra-observer variability of Kellgren–Lawrence grading, 100 randomly selected radiographs of the knee were scored by the same observer 1 month after the initial reading. To determine inter-observer variability, 100 radiographs were scored by two experienced orthopedic surgeons using the same atlas. The Kellgren–Lawrence grade (0–4) intra- and inter-variabilities were confirmed by kappa analysis to be sufficient for assessment (κ=0.86 and κ=0.80, respectively).

Incidence of osteoporosis and osteoarthritis

Cumulative incidence of osteoporosis and osteoarthritis was determined on the basis of changes in measurements between the baseline and second survey. A new case of osteoporosis was identified if an individual's BMD values at baseline were not indicative of osteoporosis, but at follow-up, BMD T-scores were lower than peak bone mass by 2.5 SD. A new case of radiographic knee osteoarthritis was identified if the Kellgren–Lawrence grade at baseline was <2 for both knees and one or both knees were assigned a grade ≥2 at follow-up. A new case of radiographic lumbar spondylosis was identified if the Kellgren–Lawrence grade at baseline was <2 for all lumbar spines and at least one spine was assigned a grade ≥2 at follow-up.

Statistical analysis

All statistical analyses were performed using STATA statistical software (STATA Corp., College Station, TX, USA). Differences in proportions were compared using the chi-squared test. Differences in continuous variables were tested for significance using analysis of variance for comparisons among multiple groups or Scheffe's least significant difference test for pairs of groups.

Logistic regression analysis was used to test the association between serum levels of 25D and the occurrence of osteoporosis at L2–4, osteoporosis in the femoral neck, knee osteoarthritis, and lumbar spondylosis. In the analysis, we used the occurrence of musculoskeletal diseases, such as osteoporosis, knee osteoarthritis, and lumbar spondylosis, as the objective variable and serum levels of 25D (ng/mL, +1 SD) as an explanatory variable, after adjusting for age (+1 year), sex (0, men; 1, women), BMI (+1 kg/m^2), and regional differences (0, mountainous area; 1, coastal area). In addition, we adjusted for factors associated with serum levels of 25D that were identified previously [21]: month of examination (0, October, November, or December; 1, January), smoking (0, never; 1, current), alcohol consumption (0, never; 1, current), serum levels of iPTH (0, <65 pg/mL; 1, ≥65 pg/mL), and total energy from daily amount of intake (+100 kcal/day) and vitamin D (+10 μg/day), calculated based on the BDHQ questionnaire. Furthermore, we adjusted for potential risk factors, including variables regarding exercise, past history, and pain that showed a significant ($p<0.05$) association with the occurrence of each musculoskeletal disease in the simple linear analysis.

Results

Eligible participants

Of the 1,690 study participants, 25D levels were measured at baseline in 1,683 individuals (595 men, 1,088 women; mean age 65.3 years [12.0], 66.3 years [11.7] in men, 64.7 years [12.1] in women). A total of 1,384 individuals (81.9 %; 466 men, 918 women; mean age 66.8 years [11.8], 67.8 years [11.6] in men, 66.4 years [11.8] in women) completed the second follow-up survey that included BMD measurements and X-ray radiography. A total of 251 individuals (14.9 %; 104 men, 147 women) dropped out of the follow-up study. The reasons for the dropouts were as follows: 40 individuals (27 men, 13 women) died, 97 individuals (32 men, 65 women) were ill, 16 individuals (5 men, 11 women) moved away, 8 individuals (4 men, 4 women) were absent, 51 (24 men, 27 women) declined to participate in the second survey, and 39 (12 men, 27 women) had other reasons for not participating in the second survey, including lack of response to the invitation. In addition, 55 individuals (3.3 %; 26 men, 29 women) participated in the second survey, but not all measurements were obtained.

Annual incidence of musculoskeletal diseases

In order to estimate cumulative incidence of osteoporosis and osteoarthritis, participants who had previously been diagnosed with osteoporosis and osteoarthritis at baseline were excluded from the estimation for the incidence of each musculoskeletal disease. Of the 1,384 participants who completed both the baseline and follow-up surveys, 204 individuals who had been diagnosed with osteoporosis at L2–4 or who had been prescribed medication for the treatment of osteoporosis at baseline were excluded. Thus, cumulative incidence of osteoporosis at L2–4 was estimated using data from 1,179 participants. Similarly, cumulative incidence for osteoporosis of the femoral neck, knee osteoarthritis, and lumbar spondylosis was estimated using data from 1,187; 728; and 530 participants, respectively (Table 1).

In those participants who completed both the baseline and follow-up surveys, the annual cumulative incidence of osteoporosis of the lumbar spine and femoral neck was estimated to be 0.76 and 1.83 %/year, respectively. The annual cumulative incidence of knee osteoarthritis and lumbar spondylosis was estimated as 3.3 and 11.4 %/year, respectively. The age and sex distribution of the incidence for each musculoskeletal disease is shown in Fig. 1.

Baseline characteristics of participants and occurrence of musculoskeletal diseases during 3-year follow-up periods

The measured baseline characteristics of the study participants, including serum levels of 25D; anthropometric measurements; lifestyle factors such as residence, smoking, alcohol consumption, and exercise; and medical history of fractures, hip pain, and knee pain, are shown in Table 1.

Serum 25D values categorized according to the occurrence or non-occurrence of musculoskeletal diseases are shown in Table 1. The mean levels of serum 25D were significantly lower in the subjects with femoral neck osteoporosis than those who did not develop femoral neck osteoporosis ($p=0.0088$). In contrast, serum 25D levels did not differ significantly between the groups with or without the occurrence of osteoporosis at L2–4 ($p=0.16$). Serum 25D levels were higher in subjects with knee osteoarthritis and lumbar spondylosis when compared to those who did not have knee osteoarthritis or lumbar spondylosis, although there were no significant differences (knee osteoarthritis, $p=0.15$; lumbar spondylosis, $p=0.10$).

When the osteoporosis at L2–4 occurrence group was compared to the non-occurrence group, participants in the occurrence group tended to have lower BMI ($p=0.031$), were more likely to be women ($p=0.011$), and did not exercise frequently ($p=0.017$). Serum PINP and urinary β-CTX and CTX-II levels were significantly higher in the osteoporosis at L2–4 group than in the non-occurrence group (PINP, $p=0.0001$; β-CTX, $p=0.004$; CTX-II, $p=0.006$). Serum levels

Table 1 Comparison of baseline characteristics of individuals with occurrence or non-occurrence of musculoskeletal diseases during the 3-year follow-up period

	Population at risk (n=1,179)			Population at risk (n=1,187)			Population at risk (n=728)			Population at risk (n=530)		
	Occurrence (n=27)	Non-occurrence (n=1,152)	p (Occurrence vs non-occurrence)	Occurrence (n=65)	Non-occurrence (n=1,122)	P (Occurrence vs non-occurrence)	Occurrence (n=71)	Non-occurrence (n=657)	P (Occurrence vs non-occurrence	Occurrence (n=182)	Non-occurrence (n=348)	P (Occurrence vs non-occurrence)
Means (standard deviations) of serum levels of 25D (ng/mL)	21.7 (5.3)	23.5 (6.6)	0.1556	21.4 (5.5)	23.6 (5.5)	0.0088**	24.2 (6.5)	23.0 (6.6)	0.1493	23.1 (6.5)	22.1 (6.1)	0.1033
Mean values (standard deviations) of selected characteristics												
Age (year)	66.8 (8.9)	62.4 (11.8)	0.06	70.2 (9.0)	61.9 (11.5)	<0.0001***	67.3 (8.2)	58.2 (11.8)	<0.0001***	63.2 (10.8)	56.8 (12.5)	0.0059**
Height (cm)	151.9 (7.8)	157.0 (8.6)	0.0022**	151.4 (6.7)	157.2 (8.7)	<0.0001***	153.9 (8.6)	158.8 (8.6)	<0.0001***	154.3 (9.2)	155.2 (7.9)	0.26
Weight (kg)	50.6 (7.4)	57.7 (10.3)	0.0004***	49.0 (6.4)	58.1 (10.3)	<0.0001***	56.0 (8.8)	56.8 (11.0)	0.56	54.9 (9.7)	53.6 (9.5)	0.15
BMI (kg/m^2)	22.0 (3.0)	23.4 (3.3)	0.0312*	21.5 (3.2)	23.5 (3.3)	<0.0001***	23.6 (2.9)	22.4 (3.2)	0.0035**	23.0 (3.2)	22.2 (3.3)	0.0107*
Frequency of selected characteristics (%)												
Female sex	85.2	61.0	0.011*	84.6	60.6	<0.001***	74.7	58.6	0.009**	71.4	83.1	0.002**
Residing in a coastal area	48.2	56.4	0.39	52.3	56.4	0.52	70.8	56.3	0.012*	42.3	61.5	<0.001***
Current smoking habit (more than once a month)	3.9	13.7	0.15	5.0	13.8	0.05	7.1	16.9	0.034*	14.4	9.8	0.12
Current alcohol consumption (more than once a month)	40.7	44.3	0.71	20.3	45.0	<0.001***	64.8	52.1	0.041*	61.5	60.7	0.85
Regularly walking outside (less than once a week, including job)	11.5	21.3	0.23	19.7	20.2	0.92	29.0	23.0	0.27	22.9	22.7	0.940
Regularly exercising outdoors (football, tennis, baseball, golf, etc.) after graduation from the last school	0.0	17.6	0.017*	7.7	18.1	0.032*	7.0	19.9	<0.001***	12.6	13.5	0.780
History of osteoporotic fractures (hip, spine [clinical, symptomatic], shoulder, wrist)	7.4	2.9	0.17	2.5	4.6	0.30	7.0	2.0	0.009**	5.0	2.9	0.220
Visited the doctor owing to pain in the hip	0.0	4.5	0.32	4.08	3.83	0.93	5.7	4.3	0.67	2.6	5.3	0.230
Visited the doctor owing to pain in either knee	19.1	22.9	0.68	26.4	22.4	0.50	25.9	11.7	0.002**	25.9	17.9	0.050*
Month of examination (January)	22.2	26.8	0.59	32.3	26.2	0.28	42.3	23.1	<0.001***	43.4	26.7	<0.001***
Mean values (standard deviation) of serum and urinary biochemical markers												
Serum levels of iPTH (pg/mL)	40.6 (14.5)	40.7 (31.5)	0.99	43.4 (14.9)	40.9 (38.3)	0.6	40.8 (18.3)	42.0 (46.6)	0.83	41.5 (28.4)	42.4 (49.3)	0.83
Serum levels of PINP (µg/L)	76.1 (21.9)	56.1 (25.4)	0.0001***	73.5 (28.7)	56.5 (26.1)	<0.0001***	59.0 (26.9)	56.3 (27.2)	0.43	59.0 (27.1)	59.2 (28.2)	0.94
Urinary levels of β-CTX (µg/mmol Cr)	245.1 (90.4)	176.4 (121.9)	0.0037**	269.5 (138.6)	176.9 (124.4)	<0.0001***	199.7 (130.2)	170.8 (113.0)	0.0452*	2,11.9 (157.7)	193.6 (134.7)	0.17

Table 1 (continued)

	Population at risk (n=1,179)			Population at risk (n=1,187)			Population at risk (n=728)			Population at risk (n=530)		
	Occurrence (n=27)	Non-occurrence (n=1,152)	p (Occurrence vs non-occurrence)	Occurrence (n=65)	Non-occurrence (n=1,122)	P (Occurrence vs non-occurrence)	Occurrence (n=71)	Non-occurrence (n=657)	P (Occurrence vs non-occurrence	Occurrence (n=182)	Non-occurrence (n=348)	P (Occurrence vs non-occurrence)
Urinary levels of CTX-II (μg/mmol Cr)	327.4 (568.9)	224.8 (173.3)	0.0060**	248.9 (126.3)	223.1 (193.0)	0.29	237.5 (175.0)	189.3 (135.2)	0.0059**	207.6 (138.4)	193.6 (154.5)	0.31
Means (standard deviations) of daily nutrition intake												
Total energy (kcal/day)	1,778.1 (458.6)	1,980.9 (600.0)	0.08	1,800.2 (535.3)	1,982.5 (597.4)	0.0172*	1,963.6 (631.4)	1,964.9 (595.4)	0.99	1,945.9 (581.3)	1,815.9 (489.3)	0.0069**
Vitamin D (μg/day)	18.8 (9.3)	20.4 (12.5)	0.51	20.7 (11.0)	20.3 (12.5)	0.77	23.9 (12.3)	18.5 (11.7)	0.0003***	19.6 (11.0)	18.0 (11.3) 0.12	

N number of subjects, *KL* Kellgren–Lawrence grade, *BMI* body mass index, *25D* 25-hydroxyvitamin D, *iPTH* intact parathyroid hormone, *PINP* procollagen type I N-terminal propeptide, *β-CTX* β-isomerized C-terminal telopeptide cross-links of type I collagen, *CTX-II* C-terminal cross-linked telopeptide type II collagen

*p<0.05; **p<0.01; ***p<0.001

of iPTH were not significantly associated with osteoporosis at L2–4.

When the osteoporosis at the femoral neck occurrence group was compared to the non-occurrence group, the participants who had osteoporosis at the femoral neck tended to be older (p<0.0001), tended to have lower BMI (p≤0.0001), were more likely to be female (p≤0.001), did not consume alcohol regularly (p<0.001), did not exercise regularly (p=0.032), and consumed less calories (p=0.017) than those in the non-occurrence group. Serum PINP and urinary β-CTX levels were significantly higher in the participants with osteoporosis at the femoral neck than in those who did not have osteoporosis at the femoral neck (p<0.0001). Serum levels of iPTH and urinary levels of CTX-II were not significantly associated with osteoporosis at the femoral neck.

When participants in the knee osteoarthritis occurrence group were compared to those who did not have knee osteoarthritis, those with knee osteoarthritis were older, had a higher BMI, were less likely to be female, resided in a coastal area, smoked less, consumed more alcohol, exercised less regularly, were more likely to have a history of osteoporotic fractures, and were more likely to have a history of medical visits because of knee pain. In addition, vitamin D levels were significantly higher in the participants with knee osteoarthritis than those in the non-occurrence group (p=0.0003). Although iPTH and PINP serum levels did not differ between the occurrence and non-occurrence groups, urinary β-CTX and CTX-II levels were significantly higher in the knee osteoarthritis occurrence group than those in the non-occurrence group (β-CTX, p=0.045; CTX-II, p=0.006).

Participants with lumbar spondylosis were older, had a higher BMI, were less likely to be female, and were more likely to have a history of past pain in either knee than the participants in the non-occurrence group. Although iPTH, PINP, β-CTX, and CTX-II levels were not different between those with lumbar spondylosis and those without, total daily energy intake was higher in the lumbar spondylosis group than in the non-occurrence group.

Logistic regression analysis between the occurrence of musculoskeletal disease and serum 25D levels

Logistic regression analysis was performed with the occurrence of musculoskeletal diseases, including osteoporosis, knee osteoarthritis, and lumbar spondylosis, as the objective variable and serum 25D levels (ng/mL, +1 SD) as the explanatory variable, after adjusting for age (+1 year), sex (0, men; 1, women), BMI (+1 kg/m^2), and regional differences (0, mountainous area; 1, coastal area). In addition, adjustments were made for factors previously shown to be associated with serum levels of 25D [20], including month of examination

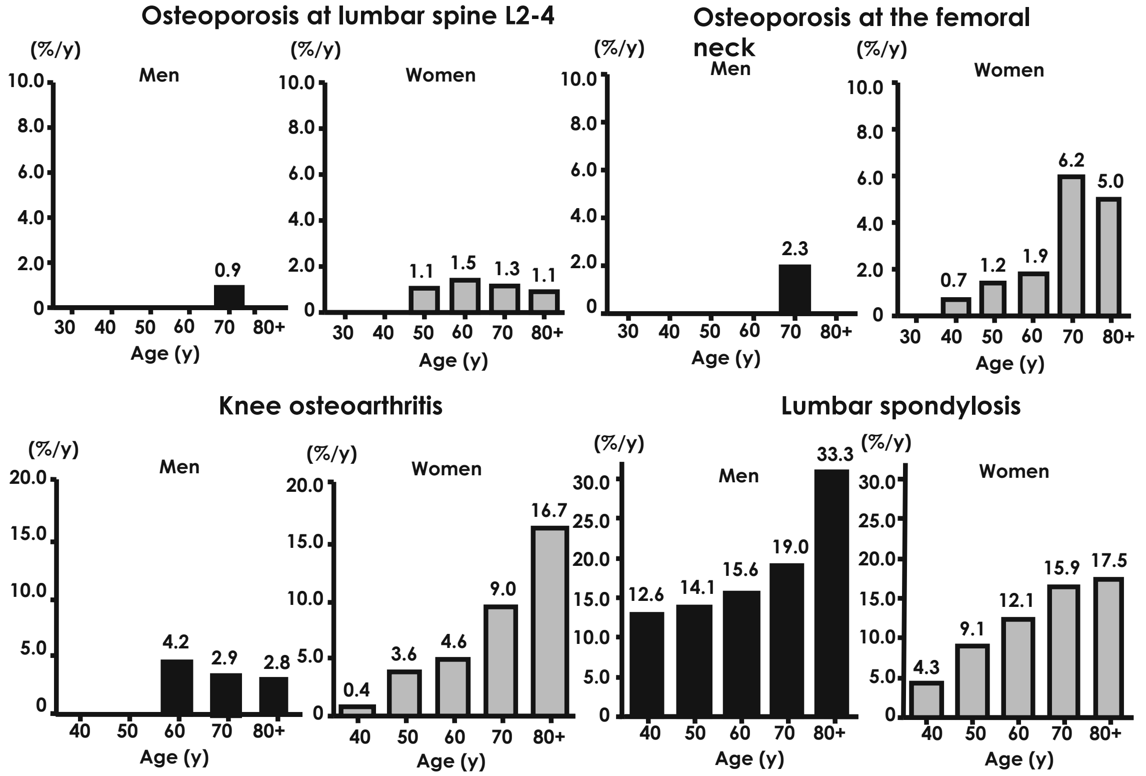

Fig. 1 Cumulative incidence (%/year) of musculoskeletal diseases (osteoporosis at the lumbar spine, osteoporosis at the femoral neck, osteoarthritis of the knee, and lumbar spondylosis) stratified by age and sex

(0, October, November, or December; 1, January), smoking (0, never; 1, current), alcohol consumption (0, never; 1, current), serum iPTH levels (0, <65 pg/mL; 1, ≥65 pg/mL), total daily energy intake (+100 kcal/day), and vitamin D (+10 μg/day) calculated according to responses on the BDHQ questionnaire. Furthermore, we adjusted for potential risk factors that showed a significant ($p<0.05$) association with the occurrence of each musculoskeletal disease in the simple linear analysis described in Table 2. Selected potential factors in each analysis were as follows: osteoporosis at L2–4, regularly exercising outdoors (0, yes; 1, no), serum levels of PINP (+1 SD), and urinary levels of β-CTX (+1 SD) and CTX-II (+1 SD); osteoporosis at femoral neck, regularly exercising outdoors (0, yes; 1, no), and urinary levels of β-CTX (+1 SD) and CTX-II (+1 SD); knee osteoarthritis, regularly exercising outdoors (0, yes; 1, no), history of osteoporotic fractures (0, no; 1, yes), history of knee pain (0, no; 1, yes), and urinary levels of β-CTX (+1 SD) and CTX-II (+1 SD); and lumbar spondylosis, history of knee pain (0, no; 1, yes).

After adjusting for potential risk factors, serum 25D levels were significantly associated with the occurrence of osteoporosis at the femoral neck (odds ratio 0.67; 95 % confidence interval 0.49–0.92; $p=0.014$). However, serum 25D levels were not significantly associated with the occurrence of knee osteoarthritis, lumbar spondylosis, or osteoporosis at L2–4.

Discussion

In the present study, using information from the population-based cohort ROAD study, we estimated the incidence of osteoporosis at L2–4 and at the femoral neck and found that higher serum 25D levels decreased the risk of future occurrence of osteoporosis at the femoral neck, but not the risk of osteoporosis at L2–4 or osteoarthritis, including knee osteoarthritis and lumbar spondylosis.

Previously, we have estimated the age–sex stratified cumulative incidence of knee osteoarthritis and lumbar spondylosis in the Japanese population, using the ROAD study of more than 2,200 subjects who participated at baseline and at the 3-year follow-up study and for whom paired radiographs and complete pain histories were obtained [22, 23]. In contrast, there are few reports estimating the incidence of osteoporosis diagnosed by BMD in the Japanese population [24, 25]. In the present study, we established the population-based cohorts of the ROAD study in identical areas to the previous studies and performed a baseline study between 2005 and 2007 and a follow-up study between 2008 and 2010. Using the data of 1,384 participants from both the baseline and follow-up studies, we estimated the annual cumulative incidence of osteoporosis at the spine L2–4 and at the femoral neck to be 0.76 and 1.83 %/year, respectively. Using the total age and sex

Table 2 Odds ratios of serum 25-hydroxyvitamin D levels influencing the occurrence of musculoskeletal diseases during the 3-year follow-up periods

		Occurrence of osteoporosis at the lumbar spine L2–4			Occurrence of osteoporosis at the femoral neck			Occurrence of knee osteoarthritis			Occurrence of lumbar spondylosis		
Explanatory variables	Reference (at the baseline)	OR	95 % CI	p	OR	95 % CI	p	OR	95 % CI	p	OR	95 % CI	p
Serum levels of 25D (ng/mL)	+1 SD	0.87	0.569–1.319	0.504	0.67	0.49–0.92	0.014*	1.23	0.90–1.69	0.198	1.01	0.81–1.28	0.900
Adjusted factors													
Age (year)	+1 year	1.05	1.00–1.09	0.043*	1.11	1.07–1.15	<0.001***	1.10	1.06–1.14	<0.001***	1.04	1.02–1.06	0.001**
Sex	0, men; 1, women	2.74	0.74–10.22	0.132	3.23	1.21–8.61	0.019*	3.24	1.24–8.45	0.016*	0.65	0.34–1.25	0.196
BMI	0, 18.5–27.5 vs 1, <18.5	3.65	0.96–14.34	0.064	8.89	3.33–23.77	<0.001***	1.00[a]	–	–	0.07	0.09–0.51	0.009**
	0, 18.5–27.5 vs 1, >27.5	0.41	0.05–3.17	0.394	0.15	0.02–1.17	0.071	2.29	0.80–6.58	0.125	2.17	1.06–4.45	0.033*
Month of examination	0, October, November, December vs 1, January	0.59	0.20–1.72	0.333	1.59	0.74–3.40	0.234	1.78	0.79–4.02	0.163	1.22	0.70–2.14	0.482
Residing region	0, mountainous area; 1, coastal area	0.71	0.28–1.81	0.467	1.69	0.80–3.58	0.171	1.18	0.53–2.64	0.688	0.71	0.42–1.20	0.197
Smoking	0, ex or never smoker; 1, current smoker	0.47	0.06–3.98	0.491	0.68	0.16–2.84	0.594	1.01	0.27–3.79	0.987	1.28	0.59–2.77	0.529
Alcohol consumption	0, ex or never drinker; 1, current drinker	1.64	0.68–3.94	0.271	0.72	0.34–1.54	0.396	0.83	0.40–1.70	0.604	0.83	0.50–1.37	0.459
Serum levels of iPTH (pg/mL)	0, <65 pg/mL; 1, ≥65 pg/mL	0.39	0.05–3.07	0.371	0.65	0.18–2.41	0.521	1.88	0.65–5.44	0.245	1.88	0.81–4.37	0.145
Total energy from daily food (kcal/day)	+100 kcal	1.00	0.90–1.11	0.991	0.93	0.86–1.01	0.101	1.01	0.94–1.08	0.768	1.04	0.98–1.10	0.179
Vitamin D from daily food (μg/day)	+10 μg	0.84	0.53–1.35	0.479	1.14	0.85–1.54	0.377	1.25	0.94–1.65	0.123	0.94	0.75–1.20	0.636
Selected adjusted factors													
Regularly exercising outdoors	0, yes; 1, no	1.00[a]	–	–	1.15	0.35–3.80	0.819	1.53	0.46–5.03	0.485	–	–	–
History of osteoporotic fractures	0, no; 1, yes	–	–	–	–	–	–	1.95	0.54–7.07	0.311	–	–	–
History of knee pain	0, no; 1, yes	–	–	–	–	–	–	1.84	0.87–3.92	0.111	1.11	0.75–1.20	0.636
Serum levels of PINP (μg/L)	+1 SD	1.51	1.00–2.26	0.040*	1.36	1.01–1.82	0.044*	–	–	–	–	–	–
Urinary levels of β-CTX (μg/mmol Cr)	+1 SD	1.05	0.69–1.61	0.802	1.18	0.91–1.51	0.206	0.76	0.512–1.13	0.176	–	–	–
Urinary levels of CTX-II (μg/mmol Cr)	+1 SD	1.09	0.83–1.44	0.528	–	–	–	1.41	0.96–2.07	0.076	–	–	–

OR odds ratio, *95 %* CI 95 % confidence interval, *25D* 25-hydroxyvitamin D, *BMI* body mass index, *iPTH* intact parathyroid hormone, *PINP* procollagen type I N-terminal propeptide, *β-CTX* β-isomerized C-terminal telopeptide cross-links of type I collagen, *CTX-II* C-terminal cross-linked telopeptide type II collagen

*$p<0.05$; **$p<0.01$; ***$p<0.001$

[a] Omitted from the model

population distributions from the Japanese 2010 census [26], our results indicate that approximately 450,000 people (50,000 men and 400,000 women) aged ≥40 years are affected by osteoporosis at L2–4 and that approximately 1,180,000 people (130,000 men and 1,050,000 women) aged ≥40 years are affected by osteoporosis at the femoral neck.

An association between inadequate vitamin D and osteoporosis has been reported previously. Deficiency of vitamin D results in decreased bone mineralization and secondary hyperparathyroidism and increased cortical bone loss and has been linked to the pathogenesis of osteoporosis and hip fractures [2, 3]. In addition, vitamin D supplementation may help to decrease fractures and falls [27, 28]. In a primary care cohort study of 1,470 postmenopausal Japanese women, there were trends of decreasing incidence of proximal femur and long bone fractures as serum 25D levels increased [29]. However, there are few reports that have assessed the predictive ability of serum 25D levels and the occurrence of osteoporosis itself. In the present study, we confirmed that higher serum 25D levels are associated with the prevention of osteoporosis occurrence, especially at the femoral neck.

There is conflicting information about the association of vitamin D and the occurrence of osteoarthritis. Few longitudinal studies have identified vitamin D deficiency as a risk factor for occurrence or progression of osteoarthritis. Specifically, Lane et al. reported that an increased risk of hip joint space narrowing is associated with low baseline serum 25D levels [11]. McAlindon et al. reported that an increased risk of knee osteoarthritis progression is associated with a low vitamin D intake or low serum 25D levels [10]. Bergink et al. reported that low dietary vitamin D intake increases the risk of progression of radiographic knee osteoarthritis [30]. In addition, cross-sectional studies have shown an association between low 25D levels and prevalent hip osteoarthritis [8, 9]. However, it has also been reported that low serum 25D levels do not increase the incidence of knee osteoarthritis. Felson et al. reported, using data from the Framingham Osteoarthritis Study cohort, that vitamin D status is unrelated to the risk of joint space or cartilage loss in knee osteoarthritis [12]. In addition, Kostari et al. followed a population of 805 subjects who participated in national health examination surveys held in 1978–1980 and 2000–2001 and found no significant association between serum 25D levels and the risk of incident knee or hip osteoarthritis [13]. Our study found no association between serum 25D levels and incident knee osteoarthritis. In addition, although no reports have examined the association between 25D and onset of lumbar spondylosis, we found no association between 25D and incident lumbar spondylosis.

In our previous report examining the association of vitamin D and musculoskeletal diseases at baseline [21], we found that the prevalence of osteoporosis at the L2–4 or at the femoral neck tended to be highest in the vitamin D deficiency group, followed by the vitamin D insufficiency and normal groups, although the groups did not differ significantly. The prevalence of knee osteoarthritis and lumbar spondylosis did not differ between vitamin D levels. In the present follow-up study using the same population, we found that higher levels of serum 25D prevented the occurrence of osteoporosis at the femoral neck, but not knee osteoarthritis or lumbar spondylosis, after adjusting for associated factors. This is the first study to confirm the association between 25D levels and the occurrence of musculoskeletal disorders, using the same population. Therefore, we concluded that the serum 25D levels would be useful in assessing the risk of future osteoporosis, but not the risk of future osteoarthritis.

There are several limitations to this study. First, although the ROAD study includes a large number of participants, these participants may not be representative of the general population. To address this, we compared the anthropometric measurements and smoking frequency and alcohol consumption between the study participants and the general Japanese population. No significant differences were found, with the exception that male ROAD study participants aged 70–74 years were significantly smaller than the overall Japanese population ($p<0.05$) [14]. This difference should be considered when evaluating potential risk factors for men aged 70–74 years. Second, we used Kellgren–Lawrence grade ≥2 as a criterion for the diagnosis of knee osteoarthritis and lumbar spondylosis. The Kellgren–Lawrence scale is a categorical index in which grade 2 is defined as definite osteophytes and grade 3 is defined as disk space narrowing with large osteophytes. Based on this scale, it would be difficult to evaluate osteophytosis and joint space narrowing separately. Thus, all cases of joint space narrowing, with and without the presence of osteophytosis, are categorized into the grade 3. Therefore, to evaluate the severity of knee osteoarthritis using quantitative parameters, a knee osteoarthritis computer-assisted diagnostic system [31] measuring minimum joint space width and area of osteophytosis is under development. In addition, a lumbar spondylosis computer-assisted diagnostic system is also under development. These systems will provide further accuracy in determining the association between the components of osteoarthritis including joint space and osteophytes and serum levels of 25D for early prevention of osteoarthritis. Finally, the measurement of the 25D level in the present study was measured on a single occasion. Thus, we could not exclude the effect of incidental life changes of participants, such as holidays or dietary changes that occurred around the examination date. Owing to budget and lack of manpower, we could not perform recurrent measurements of serum 25D levels to minimize fluctuations in 25D levels due to the effect of environmental factors. However, the large number of participants of the study means that the individual variance in serum 25D levels is diluted.

Importantly, the strength of the present study is that the participation rate in the follow-up survey was very high (81.9 %).

In conclusion, the present study revealed that serum 25D levels could predict the occurrence of osteoporosis at the femoral neck within 3 years, but not the occurrence of knee osteoarthritis or lumbar spondylosis. Raising serum 25D levels may be useful in the prevention of osteoporosis occurrence in the near future.

Acknowledgments This work was supported by the Grants-in-Aid for Scientific Research to NY (B23390172 and B20390182), to TA (C20591737), and to SM (C20591774); for Young Scientists to HO (A18689031); and for Collaborating Research with NSF to NY (Director; 08033011-00262) from the Ministry of Education, Culture, Sports, Science and Technology and by H17-Men-eki-009 (Director, KN), H18-Choujyu-037 (Director, TN), H20-Choujyu-009 (Director, NY), H23-Chojyu-002 (Director, TA), H25-Nanchi-to (Men)-005 (Director, ST), and H25-Chojyu-007 (Director, NY) from the Ministry of Health, Labour and Welfare in Japan. This study was also supported by grants from the Japan Osteoporosis Society (NY, SM, HO, and TA) and by research aid from the Japanese Orthopaedic Association (JOA-Subsidized Science Project Research 2006-1 and 2010-2; Director, HK). The authors wish to thank Dr. Takako Nojiri and Mr. Kazuhiro Hatanaka of the Gobo Public Health Centre; Dr. Naoki Hirabayashi of the Kawakami Clinic, Hidakagawa Town; Mrs. Tomoko Takijiri, Mrs. Kumiko Shinou, Mrs. Rie Takiguchi, Mrs. Kyoko Maeda, Ms. Ikuyo Ueyama, Mrs. Michiko Mori, Mrs. Hisayo Sugimoto, and other members of the public office in Hidakagawa Town; Dr. Shinji Matsuda of the Shingu Public Health Centre; and Mrs. Tamako Tsutsumi, Mrs. Kanami Maeda, Mr. Shoichi Shimoichi, Mrs. Megumi Takino, Mrs. Shuko Okada, Mrs. Kazuyo Setoh, Mrs. Chise Ryouno, Mrs. Miki Shimosaki, Mrs. Chika Yamaguchi, Mrs. Yuki Shimoji, and other members of the public office in Taiji Town for their assistance in locating and scheduling participants for examinations. We also thank Ms. Kyoko Yoshimura, Mrs. Toki Sakurai, and Mrs. Saeko Sahara for their assistance with data reduction and administration.

Conflicts of interest Noriko Yoshimura, Shigeyuki Muraki, Hiroyuki Oka, Kozo Nakamura, Hiroshi Kawaguchi, Sakae Tanaka, and Toru Akune declare that they have no conflict of interest.

References

1. Ministry of Health. Labour and Welfare (2010) Outline of the results of the National Livelihood Survey 2010. http://www.mhlw.go.jp/toukei/saikin/hw/k-tyosa/k-tyosa10/4-2.html. Accessed 12 September 2012
2. Lips P (2001) Vitamin D deficiency and secondary hyperparathyroidism in the elderly: consequences for bone loss and fractures and therapeutic implications. Endocr Rev 22:477–501
3. Bischoff-Ferrari HA, Zhang Y, Kiel DP, Felson DT (2005) Positive association between serum 25-hydroxyvitamin D level and bone density in osteoarthritis. Arthritis Rheum 53:821–826
4. Bischoff-Ferrari HA, Kiel DP, Dawson-Hughes B, Orav JE, Li R, Spiegelman D, Dietrich T, Willett WC (2009) Dietary calcium and serum 25-hydroxyvitamin D status in relation to BMD among U.S. adults. J Bone Miner Res 24:935–942
5. Mithal A, Wahl DA, Bonjour JP, Burckhardt P, Dawson-Hughes B, Eisman JA, El-Hajj Fuleihan G, Josse RG, Lips P, Morales-Torres J, IOF Committee of Scientific Advisors (CSA) Nutrition Working Group (2009) Global vitamin D status and determinants of hypovitaminosis D. Osteoporos Int 20:1807–1820
6. Hanley DA, Cranney A, Jones G, Whiting SJ, Leslie WD, Cole DE, Atkinson SA, Josse RG, Feldman S, Kline GA, Rosen C, Guidelines Committee of the Scientific Advisory Council of Osteoporosis Canada (2010) Vitamin D in adult health and disease: a review and guideline statement from osteoporosis Canada. CMAJ 182:E610–618
7. Dawson-Hughes B, Mithal A, Bonjour JP, Boonen S, Burckhardt P, Fuleihan GE, Josse RG, Lips P, Morales-Torres J, Yoshimura N (2010) IOF position statement: vitamin D recommendations for older adults. Osteoporos Int 21:1151–1154
8. Ding C, Cicuttini F, Parameswaran V, Burgess J, Quinn S, Jones G (2009) Serum levels of vitamin D, sunlight exposure, and knee cartilage loss in older adults: the Tasmanian older adult cohort study. Arthritis Rheum 60:1381–1389
9. Chaganti RK, Parimi N, Cawthon P, Dam TL, Nevitt MC, Lane NE (2010) Association of 25-hydroxyvitamin D with prevalent osteoarthritis of the hip in elderly men: the osteoporotic fractures in men study. Arthritis Rheum 62:511–514
10. McAlindon TE, Felson DT, Zhang Y, Hannan MT, Aliabadi P, Weissman B (1996) Relation of dietary intake and serum levels of vitamin D to progression of osteoarthritis of the knee among participants in the Framingham Study. Ann Intern Med 125:353–359
11. Lane NE, Gore LR, Cummings SR, Hochberg MC, Scott JC, Williams EN (1999) Serum vitamin D levels and incident changes of radiographic hip osteoarthritis: a longitudinal study. Study of osteoporotic fractures research group. Arthritis Rheum 42:854–860
12. Felson DT, Niu J, Clancy M, Aliabadi P, Sack B, Guermazi A, Hunter DJ, Amin S, Rogers G, Booth SL (2007) Low levels of vitamin D and worsening of knee osteoarthritis: results of two longitudinal studies. Arthritis Rheum 56:129–136
13. Konstari S, Paananen M, Heliövaara M, Knekt P, Marniemi J, Impivaara O, Arokoski J, Karppinen J (2012) Association of 25-hydroxyvitamin D with the incidence of knee and hip osteoarthritis: a 22-year follow-up study. Scand J Rheumatol 41:124–131
14. Yoshimura N, Muraki S, Oka H, Mabuchi A, En-Yo Y, Yoshida M, Saika A, Yoshida H, Suzuki T, Ishibashi H, Kawaguchi H, Nakamura K, Akune T (2009) Prevalence of knee osteoarthritis, lumbar spondylosis, and osteoporosis in Japanese men and women: the research on osteoarthritis/osteoporosis against disability study. J Bone Miner Metab 27:620–628
15. Yoshimura N, Muraki S, Oka H, Kawaguchi H, Nakamura K, Akune T (2010) Cohort profile: research on osteoarthritis/osteoporosis against disability study. Int J Epidemiol 39:988–995
16. Kobayashi S, Honda S, Murakami K, Sasaki S, Okubo H, Hirota N, Notsu A, Fukui M, Date C (2012) Both comprehensive and brief self-administered diet history questionnaires satisfactorily rank nutrient intakes in Japanese adults. J Epidemiol 22:151–159
17. Hollis BW, Kamerud JQ, Selvaag SR, Lorenz JD, Napoli JL (1993) Determination of vitamin D status by radioimmunoassay with an 125I-labeled tracer. Clin Chem 39:529–533
18. World Health Organization (1994) Assessment of fracture risk and its application to screening for postmenopausal osteoporosis. WHO Tech Rep Ser 843:1–129
19. Orimo H, Hayashi Y, Fukunaga M, Sone T, Fujiwara S, Shiraki M, Kushida K, Miyamoto S, Soen S, Nishimura J, Oh-Hashi Y, Hosoi T, Gorai I, Tanaka H, Igai T, Kishimoto H, Osteoporosis Diagnostic Criteria Review Committee: Japanese Society for Bone and Mineral Research (2001) Diagnostic criteria for primary osteoporosis: year 2000 revision. J Bone Miner Metab 19:331–337

20 Kellgren JH, Lawrence LS (1957) Radiological assessment of osteoarthrosis. Ann Rheum Dis 16:494–502

21. Yoshimura N, Muraki S, Oka H, Morita M, Yamada H, Tanaka S, Kawaguchi H, Nakamura K, Akune T (2013) Profiles of vitamin D

insufficiency and deficiency in Japanese men and women: association with biological, environmental, and nutritional factors and coexisting disorders: the ROAD study. Osteoporos Int 24:2775–2778
22. Muraki S, Akune T, Oka H, Ishimoto Y, Nagata K, Yoshida M, Tokimura F, Nakamura K, Kawaguchi H, Yoshimura N (2012) Incidence and risk factors for radiographic knee osteoarthritis and knee pain in Japanese men and women: a longitudinal population-based cohort study. Arthritis Rheum 64:1447–1456
23. Muraki S, Akune T, Oka H, Ishimoto Y, Nagata K, Yoshida M, Tokimura F, Nakamura K, Kawaguchi H, Yoshimura N (2012) Incidence and risk factors for radiographic lumbar spondylosis and lower back pain in Japanese men and women: the ROAD study. Osteoarthr Cartil 20:712–718
24. Yoshimura N, Muraki S, Oka H, Kawaguchi H, Nakamura K, Akune T (2011) Biochemical markers of bone turnover as predictors for occurrence of osteoporosis and osteoporotic fractures in men and women: ten-year follow-up of the Taiji cohort study. Mod Rheumatol 21:608–620
25. Yoshimura N, Muraki S, Oka H, Mabuchi A, Kinoshita H, Yoshida M, Kawaguchi H, Nakamura K, Akune T (2009) Epidemiology of lumbar osteoporosis and osteoarthritis and their causal relationship—is osteoarthritis a predictor for osteoporosis or vice-versa?: the Miyama study. Osteoporos Int 20:999–1008
26. Portal site of Official Statistics of Japan (2010) Population Census 2010. http://www.e-stat.go.jp/SG1/estat/NewListE.do?tid=000001039448. Accessed 17 Aug 2014
27. Bischoff-Ferrari HA, Willett WC, Orav EJ, Lips P, Meunier PJ, Lyons RA, Flicker L, Wark J, Jackson RD, Cauley JA, Meyer HE, Pfeifer M, Sanders KM, Stahelin HB, Theiler R, Dawson-Hughes B (2012) A pooled analysis of vitamin D dose requirements for fracture prevention. N Engl J Med 367:40–49
28. Bischoff-Ferrari HA, Willett WC, Orav JE, Kiel DP, Dawson-Hughes B (2011) Fall prevention with vitamin D. BMJ 342:d2608
29. Tanaka S. Kuroda T. Yamazaki Y. Shiraki Y. Yoshimura N. Shiraki M (2013) Serum 25-hydroxyvitamin D below 25 ng/mL is a risk factor for long bone fracture comparable to bone mineral density in Japanese postmenopausal women. J Bone Miner Metab. doi: 10.1007/s00774-013-0520-3
30. Bergink AP, Uitterlinden AG, Van Leeuwen JP, Buurman CJ, Hofman A, Verhaar JA, Pols HA (2009) Vitamin D status, bone mineral density, and the development of radiographic osteoarthritis of the knee: the Rotterdam study. J Clin Rheumatol 15:230–237
31. Oka H, Muraki S, Akune T, Mabuchi A, Suzuki T, Yoshida H, Yamamoto S, Nakamura K, Yoshimura N, Kawaguchi H (2008) Fully automatic quantification of knee osteoarthritis severity on plain radiographs. Osteoarthr Cartil 16:1300–1306

J Bone Miner Metab (2015) 33:221–229
DOI 10.1007/s00774-014-0583-9

ORIGINAL ARTICLE

Prevalence of diffuse idiopathic skeletal hyperostosis (DISH) of the whole spine and its association with lumbar spondylosis and knee osteoarthritis: the ROAD study

Ryohei Kagotani · Munehito Yoshida · Shigeyuki Muraki · Hiroyuki Oka · Hiroshi Hashizume · Hiroshi Yamada · Yoshio Enyo · Keiji Nagata · Yuyu Ishimoto · Masatoshi Teraguchi · Sakae Tanaka · Kozo Nakamura · Hiroshi Kawaguchi · Toru Akune · Noriko Yoshimura

Received: 23 August 2013 / Accepted: 23 February 2014 / Published online: 13 March 2014

Abstract We aimed to assess the prevalence of diffuse idiopathic skeletal hyperostosis (DISH) and its association with lumbar spondylosis (LS) and knee osteoarthritis (KOA) using a population-based cohort study entitled Research on Osteoarthritis/osteoporosis Against Disability (ROAD). In the baseline ROAD study, which was performed between 2005 and 2007, 1,690 participants in mountainous and coastal areas underwent anthropometric measurements and radiographic examinations of the whole spine (cervical, thoracic, and lumbar) and both knees. They also completed an interviewer-administered questionnaire. Presence of DISH was diagnosed according to Resnick criteria, and LS and KOA were defined as Kellgren-Lawrence (KL) grade ≥3. Among the 1,690 participants, whole-spine radiographs of 1,647 individuals (97.5 %; 573 men, 1,074 women; mean age, 65.3 years) were evaluated. Prevalence of DISH was 10.8 % (men 22.0 %, women 4.8 %), and was significantly higher in older participants (presence of DISH 72.3 years, absence of DISH 64.4 years) and mainly distributed at the thoracic spine (88.7 %). Logistic regression analysis revealed that presence of DISH was significantly associated with older age [+1 year, odds ratio (OR): 1.06, 95 % confidence interval (CI): 1.03–1.14], male sex (OR: 5.55, 95 % CI: 3.57–8.63), higher body mass index (+1 kg/m^2, OR: 1.08, 95 % CI: 1.02–1.14), presence of LS (KL2 vs KL0: 1, OR: 5.50, 95 % CI: 2.81–10.8) (KL ≥3 vs KL0: 1, OR: 4.09, 95 % CI: 2.08–8.03), and presence of KOA (KL ≥3 vs KL0: 1, OR: 1.89, 95 % CI: 1.14–3.10) after adjusting for smoking, alcohol consumption, and residential area (mountainous vs coastal). This cross-sectional population-based study clarified the prevalence of DISH in general inhabitants and its significant association with LS and severe KOA.

Keywords Prevalence · Diffuse idiopathic skeletal hyperostosis · Knee osteoarthritis · Lumbar spondylosis · ROAD study

R. Kagotani · M. Yoshida (✉) · H. Hashizume · H. Yamada · Y. Enyo · K. Nagata · Y. Ishimoto · M. Teraguchi
Department of Orthopaedic Surgery, Wakayama Medical University, 811-1 Kimiidera, Wakayama 641-8509, Japan
e-mail: yoshimunenoriko@yahoo.co.jp

S. Muraki · T. Akune
Department of Clinical Motor System Medicine, 22nd Century Medical and Research Centre, Graduate School of Medicine, The University of Tokyo, Tokyo, Japan

H. Oka · N. Yoshimura
Department of Joint Disease Research, 22nd Century Medical and Research Centre, Graduate School of Medicine, The University of Tokyo, Tokyo, Japan

S. Tanaka · H. Kawaguchi
Department of Orthopaedic Surgery, Graduate School of Medicine, The University of Tokyo, Tokyo, Japan

K. Nakamura
Rehabilitation Services Bureau, National Rehabilitation Centre for Persons with Disabilities, Tokorozawa, Japan

Introduction

Diffuse idiopathic skeletal hyperostosis (DISH) is characterised by calcification and ossification of soft tissue such as entheses and joint capsules [1]. Resnick and Niwayama specifically defined DISH as the radiographic finding of calcification or ossification along the anterolateral aspects of at least 4 contiguous vertebral levels (across 3 disc spaces), with relative preservation of disc height in the involved vertebral segments and without degenerative disc disease [2]. In 1998, Mata and co-workers [3] developed a scoring system such that the presence of DISH could be assessed reproducibly. This system scores individuals who fulfill the Resnick criteria by numerically classifying each vertebral level based on the amount of ossification and whether partial or complete bridging of the disc space is present [3].

Although some reports have indicated a significant association between DISH and ossification of the posterior longitudinal ligament (OPLL) [4–7], DISH is thought to be an asymptomatic condition in many affected individuals; however, several clinical symptoms have been described including pain, limited range of spinal motion, and increased susceptibility to unstable spinal fractures after trivial trauma [8]. In addition, dysphagia and airway obstruction at the cervical levels [8, 9], as well as radiculopathy and spinal injury after spinal fracture [10–12], have been reported as clinical manifestations of DISH.

Although the condition is recognised in many parts of the world [13–20], there are relatively few population-based studies concerning its prevalence. Such data are important in order to characterise the burden of the disease. In addition, regarding its characteristics, several epidemiologic studies have reported that DISH is observed mainly in the elderly, and that prevalence increases with age [18, 19]. Men are affected by DISH much more frequently than women [20]. Although metabolic disturbance is hypothesised to be a factor [21, 22], the aetiology of the condition remains unknown.

Based on the definition of DISH as the radiographic finding of calcification or ossification, it appears that the condition might be associated with osteoarthritis (OA) of the spine. The severity of OA, as observed on radiography, was determined according to Kellgren-Lawrence (KL) grading as follows [23]: KL0, normal; KL1, slight osteophytes; KL2, definite osteophytes; KL3, joint or intervertebral space narrowing with large osteophytes; and KL4, bone sclerosis, joint or intervertebral space narrowing, and large osteophytes. KL2 is commonly used as the diagnostic criterion for lumbar spondylosis (LS) or OA at other sites. Thus, LS—defined as KL2 (defined as the definite presence of osteophytes)—could easily be associated with DISH. However, there are few reports to confirm the association between DISH and severe LS with the criterion of KL3 (defined as the presence of intervertebral space narrowing) or KL4 (defined as the presence of bone sclerosis). In addition, there are few reports to clarify the association between DISH and OA at other sites, such as the knees.

We conducted a survey, known as the Research on Osteoarthritis/osteoporosis Against Disability (ROAD) study, using a population-based cohortto determine the prevalence of DISH using lateral whole-spine radiography in recently examined subjects, which included men and women in Japan. Another aim of our study was to clarify the association of DISH with LS and knee osteoarthritis (KOA) based on KL grade.

Materials and methods

Outline of the ROAD study

We conducted the present study using the cohorts established in 2005 for the ROAD study—a nationwide, prospective study of OA comprising population-based cohorts in several communities in Japan. Details of the cohort profile have been reported elsewhere [24, 25]. Briefly, from 2005 to 2007, we developed a baseline database that included clinical and genetic information of 3,040 residents of Japan (1,061 men, 1,979 women) with a mean age of 70.3 (SD, 11) years [men: 71 (SD, 10.7) years, women: 69.9 (SD, 11.2) years]. Subjects were recruited from resident registration listings in three communities with different characteristics: 1,350 subjects (465 men, 885 women) from an urban region in Itabashi, Tokyo; 864 (319 men, 545 women) from a mountainous region in Hidakagawa, Wakayama; and 826 (277 men, 549 women) from a coastal region in Taiji, Wakayama.

Participants completed an interviewer-administered questionnaire of 400 items that included lifestyle information, such as occupation, smoking habits, alcohol consumption, family history, medical history, physical activity, reproductive variables, and health-related quality of life. The questionnaire was prepared by modifying the questionnaire used in the Osteoporotic Fractures in Men Study (MrOS) [26]; some new items also were added to the modified questionnaire. Participants were asked whether they took prescription medication daily or nearly every day (no = 0, yes = 1). If the participants did not know the reason for the prescribed medication, they were asked to bring their medication to the medical doctor (NY).

Anthropometric measurements, including height (cm), body weight (kg), arm span (cm), bilateral grip strength (kg), and body mass index (BMI, kg/m^2) were recorded for each patient. Medical information was recorded by experienced orthopaedic surgeons on systematic, local, and mental status, including information on back, knee, and hip pain; swelling and range of motion of the joints; and patellar and Achilles tendon reflexes.

Eligible subjects of the present study

In the ROAD study, radiographic examination of the thoracic spine was performed only in subjects in mountainous and coastal regions. These subjects also underwent blood and urinary examinations. In the present study, among 1,690 subjects (596 men, 1,094 women) in mountainous and coastal regions in the ROAD study, we excluded 43 whose radiograph quality was so poor that it was difficult to observe the sites of thoracic–lumbar junction and lumbosacral junction; thus, we analysed 1,647 participants (573 men, 1,074 women) ranging in age from 23 to 94 years (mean: 65.3 years, men: 66.3 years, women: 64.7 years).

Study participants provided written informed consent, and the study was approved by the ethics committees of the University of Wakayama Medical University (No. 373) and the University of Tokyo (No. 1264 and No. 1326).

Radiographic assessment

Plain radiographs of the cervical, thoracic, and lumbar spine in the anteroposterior and lateral views, and bilateral knees in the anteroposterior view with weight-bearing and foot-map positioning were obtained. DISH was diagnosed according to the following criteria, defined by Resnick and Niwayama [2]: (1) flowing ossification along the lateral aspect of at least 4 contiguous vertebral bodies, (2) relative preservation of intervertebral disc height in the involved segments, and (3) absence of epiphyseal joint bony enclosing and sacroiliac joint erosion. In the assessment of lateral radiographs, since it was difficult to read the C7/Th1 to T3/4 vertebral levels, 'whole spine' in the present study implies radiographs assessed from the C0/1 to C6/7, Th4/5 to Th12/L1, and L1/L2 to L5/S1 levels.

The radiographic severity of OA was determined according to the above-mentioned KL grade [20]. Radiographs of each site (i.e., vertebrae and knees) were examined by a single experienced orthopaedic surgeon (SM) who was blinded to the participants' clinical status. In the present study, the maximum grade, diagnosed in at least 1 intervertebral level of the lumbar spine or at least 1 knee joint, was regarded as the subject's KL grade.

Statistical analysis

All statistical analyses were performed using STATA statistical software (STATA Corp., College Station, TX, USA). Differences in proportions were compared using the Chi-square test. Differences in continuous variables were tested for significance using analysis of variance for comparisons among multiple groups or Scheffe's least significant difference test for pairs of groups.

To test the association between the presence of DISH and LS and/or KOA, we used logistic regression analysis. In the analysis, we used presence of DISH as the objective variable (absence = 0, presence = 1), and severity of prevalent LS (KL0, 1 = 0 vs. KL2 = 1; KL0, 1 = 0 vs. KL3 or 4 = 2) and KOA (KL0, 1 = 0 vs. KL2 = 1; KL0, 1 = 0 vs. KL3 or 4 = 2) as explanatory variables, in addition to basic characteristics such as age (+1 year), sex (men = 1, women = 0), BMI (+1 kg/m^2), and regional differences (mountainous area = 0, coastal area = 1). Other potential associated factors were selected with significant or marginal ($p < 0.1$) association with DISH status in a simple linear analysis. The selected explanatory variables for logistic regression analysis are described in the Results section.

Results

Prevalence of DISH was 10.8 % (men: 22.0 %, women: 4.8 %), and was significantly higher in men than in women. Figure 1 shows the prevalence of DISH according to age and sex. Prevalence increased with age in both men and women. Prevalence in subjects classified by age-strata—<50, 50–59, 60–69, 70–79, and ≥80 years—was 1.8, 11.7, 15.4, 32.6, and 39.6 % in men, and 0.7, 1.5, 3.5, 7.6, and 11.8 % in women, respectively.

Table 1 shows the baseline characteristics of the 1,647 participants with and without DISH. In total, subjects with DISH tended to be older, taller, heavier, and have higher BMI than those without DISH ($p < 0.0001$). In the comparison classified by sex, age was significantly higher in those with DISH in both men and women ($p < 0.0001$). In women, mean weight and BMI were significantly higher in those with DISH than in those without DISH (weight: $p < 0.05$, BMI: $p < 0.0001$).

Prevalence of DISH was lower in individuals residing in a coastal area. Individuals with DISH had a higher frequency of smoking and alcohol consumption ($p < 0.05$). The difference in the residing area was significantly observed in men. However, in the comparison classified by sex, differences in smoking and drinking were diluted (Table 1).

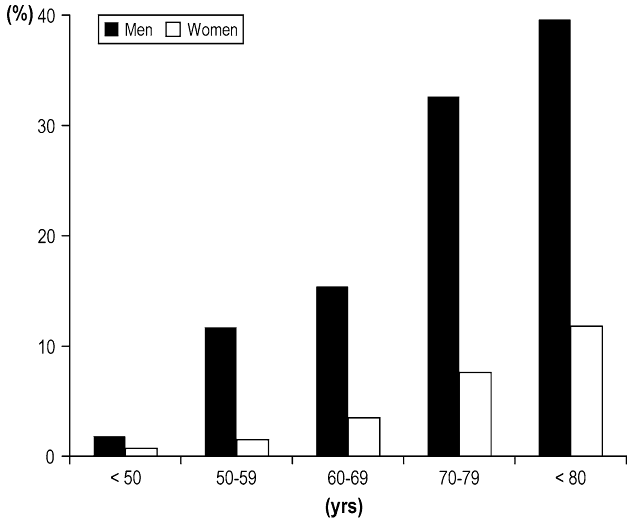

Fig. 1 Prevalence of diffuse idiopathic skeletal hyperostosis (DISH) according to sex and age

Table 1 Mean values (standard deviations) of the anthropometric measurements and the prevalence of lifestyle factors for the participants classified by presence or absence of DISH

	Total (n = 1647)			Men (n = 573)			Women (n = 1074)		
	DISH (−) n = 1470	DISH (+) n = 177	p	DISH (−) n = 447	DISH (+) n = 126	p	DISH (−) n = 1023	DISH (+) n = 51	p
Age (years)	64.4 (12.1)	72.3 (8.4)	<0.0001***	64.6 (12.1)	72.4 (8.2)	<0.0001***	64.3 (12.2)	71.9 (8.8)	<0.0001***
Height (cm)	154.7 (9.2)	158.6 (8.8)	<0.0001***	163.7 (7.3)	162.5 (6.7)	0.0918	150.8 (7.0)	148.9 (5.5)	0.0589
Weight (kg)	55.9 (10.6)	60.1 (10.5)	<0.0001***	62.3 (11.0)	62.1 (10.0)	0.8806	51.9 (8.8)	55.0 (10.3)	0.0126*
BMI (kg/m^2)	22.9 (3.4)	23.8 (3.3)	0.0005***	23.2 (3.2)	23.5 (2.9)	0.3378	22.8 (3.4)	24.7 (3.9)	0.0001***
Residing in the coastal area (%)	50.48	40.11	0.009**	50.3	35.7	0.004**	50.5	51.0	0.951
Current smoking habit (regularly, ≥1 month) (%)	11.9	21.3	<0.001***	29.9	29.0	0.858	3.8	2.0	0.506
Current alcohol consumption (regularly, ≥1 month) (%)	38.7	48.0	0.017*	68.5	61.1	0.122	25.7	15.7	0.108
Presence of LS (KL grade ≥2) (%)	59.1	93.8	<0.001***	72.0	94.4	<0.001***	53.4	92.2	<0.001***
Presence of LS (KL grade ≥3) (%)	35.6	48.0	0.001**	35.4	45.2	0.043*	35.7	54.9	0.005**
Presence of KOA (KL grade ≥2) (%)	48.2	65.5	<0.001***	35.5	58.7	<0.001***	53.8	83.3	<0.001***
Presence of KOA (KL grade ≥3) (%)	18.4	34.5	<0.001***	11.0	27.0	<0.001***	21.7	54.2	<0.001***

DISH diffuse idiopathic skeletal hyperostosis, *BMI* body mass index, *LS* lumbar spondylosis, *KOA* knee osteoarthritis, *KL grade* Kellgren-Lawrence grade

DISH (−) absence of DISH, *DISH (+)* presence of DISH

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 1 also shows the prevalence of LS and KOA defined by KL grade ≥2 and grade ≥3, according to DISH status. In total, the prevalence of LS was higher in those with DISH than in those without DISH ($p = 0.001$). A similar tendency was observed in the prevalence of KOA ($p < 0.001$). This tendency also was noted in the comparison classified by sex.

We classified subjects with DISH into 4 types: (1) cervical, ossification along the lateral aspect of at least 4 contiguous vertebral bodies only in the cervical region (C0/1–C6/7); (2) thoracic, ossification along the lateral aspect of at least 4 contiguous vertebral bodies only in the thoracic region (Th4/5–Th12/L1); (3) lumbar, ossification along the lateral aspect of at least 4 contiguous vertebral bodies only in the lumbar region (L1/2–L5/S1); and (4) diffuse, ossification along the lateral aspect of at least 4 contiguous vertebral bodies in more than 2 regions or through more than 2 regions. Table 2 shows the prevalence of DISH classified by location in the spine. A total of 89 % was shown to be thoracic, whereas the remaining was diffuse; there were no subjects with cervical-type or lumbar-type DISH.

Figure 2 shows the distribution of DISH classified by vertebral level (Th4/5–LS/S1). Among diffuse-type DISH, although 2 subjects had ossification in the cervical region, the cervical site is excluded from the figure. Figure 2 shows that ossification was observed mainly in the middle-lower thoracic sites (Th7/8–Th9/10).

Logistic regression analysis was performed with DISH as the objective variable, LS and KOA as explanatory variables, and patient characteristics including age, sex, BMI, regional differences, smoking, and alcohol consumption as potential risk factors. Presence of DISH was significantly associated with presence of LS (KL2 vs KL0: 1, KL ≥3 vs KL0: 1) and KOA (KL ≥3 vs KL0: 1). Among other potential associated factors, older age, male sex, and higher BMI remained as significantly associated with the presence of DISH (Table 3).

Table 2 Number (proportion, %) of DISH (+) patients classified by spinal ossification site

Type of DISH	Total	Men	Women
Cervical type	0 (0.0 %)	0 (0.0 %)	0 (0.0 %)
Thoracic type	157 (88.7 %)	111 (88.1 %)	46 (90.2 %)
Lumbar type	0 (0.0 %)	0 (0.0 %)	0 (0.0 %)
Diffuse type	20 (11.3 %)	15 (11.9 %)	5 (9.8 %)
Total	177 (100.0 %)	126 (100.0 %)	51 (100.0 %)

Cervical type: Ossification along the lateral aspect of at least four contiguous vertebral bodies existing only in the cervical region (C0/1–C6/7)

Thoracic type: Ossification along the lateral aspect of at least four contiguous vertebral bodies existing only in the thoracic region (Th4/5–Th12/L1)

Lumbar type: Ossification along the lateral aspect of at least four contiguous vertebral bodies existing only in the lumbar region (L1/2–L5/S1)

Diffuse type: Ossification along the lateral aspect of at least four contiguous vertebral bodies existing in more than 2 regions or through more than 2 regions

Finally, to clarify the association of DISH with LS and KOA, we performed logistic regression analysis using DISH as an objective variable, LS and KOA as explanatory variables, and patient characteristics including age, sex, BMI, regional differences, smoking, and alcohol consumption as potential risk factors. Presence of DISH was significantly associated with presence of LS (KL2 vs KL0: 1, KL ≥3 vs KL0: 1) and KOA (KL ≥3 vs KL0: 1) independently (Table 4).

Discussion

In the present study, using lateral whole-spine radiographs of recently examined population-based samples, we estimated that the prevalence of DISH was one-tenth of the population, which consisted of participants from the ROAD study. The subjects with DISH tended to be older and had bigger body build than those without DISH. In addition, DISH was observed more frequently in men than

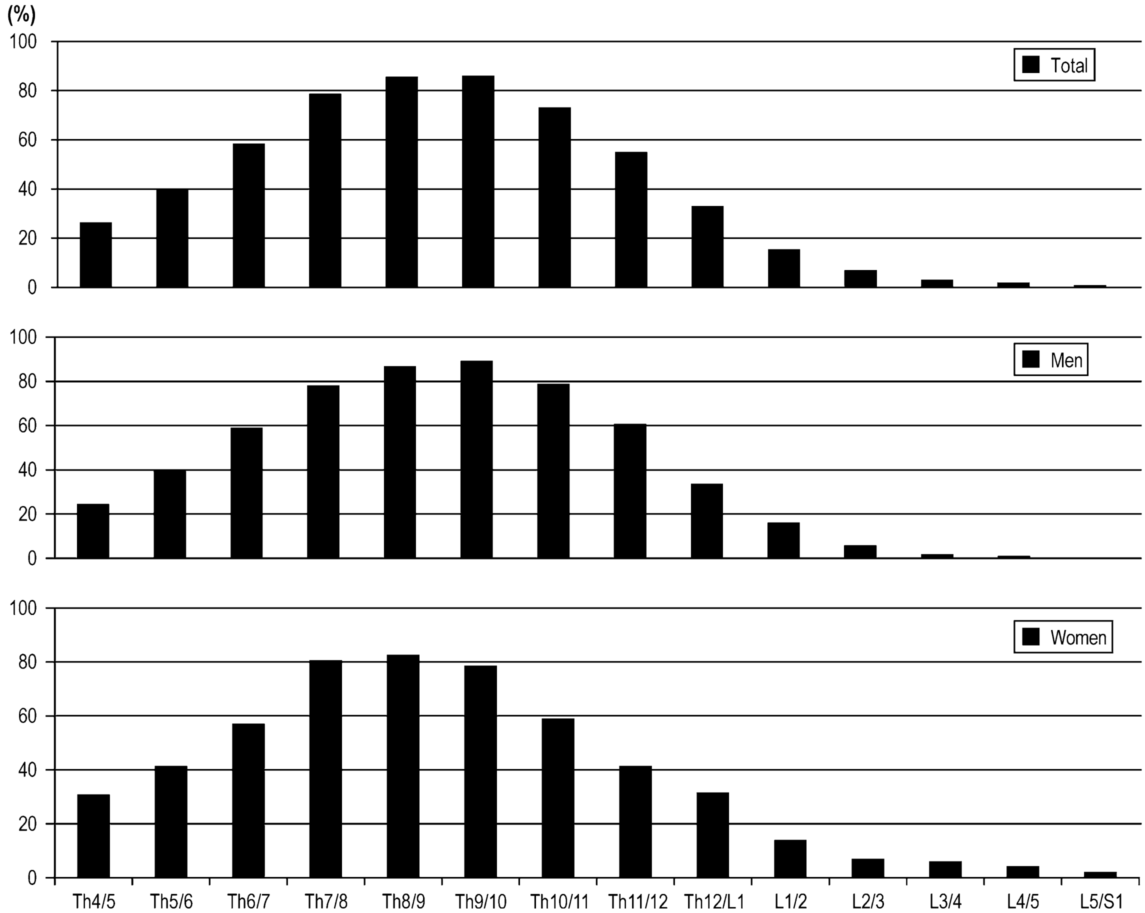

Fig. 2 Prevalence of diffuse idiopathic skeletal hyperostosis (DISH) in each vertebral level, classified by sex

Table 3 Odds ratios of lumbar spondylosis or knee osteoarthritis, and potentially associated factors for the presence of DISH vs. absence of DISH

Explanatory variables	Category	OR	95 % CI	p
Lumbar spondylosis				
Presence of LS	0: KL grade = 0, 1, 1: KL grade = 2	5.80	2.97–11.3	<0.001***
	0: KL grade = 0, 1, 2: KL grade ≥3	4.54	2.34–8.84	<0.001***
Age (years)	+1 year	1.07	1.05–1.09	<0.001***
Gender	1: men, 0: women	4.61	3.05–6.99	<0.001***
Region	0: mountainous area, 1: coastal area	0.88	0.61–1.26	0.475
BMI (kg/m^2)	+1 kg/m^2	1.11	1.05–1.17	<0.001***
Smoking	0: ex or never smoker, 1: current smoker	1.65	1.04–2.63	0.034*
Alcohol consumption	0: ex or never drinker, 1: current drinker	0.82	0.56–1.22	0.329
Knee osteoarthritis				
Presence of KOA	0: KL grade = 0, 1, 1: KL grade = 2	1.34	0.85–2.10	0.211
	0: KL grade = 0, 1, 2: KL grade ≥3	2.15	1.32–3.52	0.002**
Age (years)	+1 year	1.07	1.04–1.09	<0.001***
Gender	1: men, 0: women	6.90	4.48–10.6	<0.001***
Region	0: mountainous area, 1: coastal area	0.95	0.65–1.37	0.771
BMI (kg/m^2)	+1 kg/m^2	1.09	1.03–1.15	0.002**
Smoking	0: ex or never smoker, 1: current smoker	1.52	0.95–2.42	0.079
Alcohol consumption	0: ex or never drinker, 1: current drinker	0.85	0.58–1.26	0.431

DISH diffuse idiopathic skeletal hyperostosis, *BMI* body mass index, *LS* lumbar spondylosis, *KOA* knee osteoarthritis, *KL grade* Kellgren-Lawrence grade

OR odds ratios, *95 % CI* 95 % confidence interval

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4 Odds ratios of lumbar spondylosis and knee osteoarthritis, and potentially associated factors for the presence of DISH vs. absence of DISH

Explanatory variables	Category	OR	95 % CI	p
Presence of LS (KL grade = 2)	vs. KL grade = 0, 1	5.50	2.81–10.8	<0.001***
Presence of LS (KL grade ≥3)	vs. KL grade = 0, 1	4.09	2.08–8.03	<0.001***
Presence of KOA (KL grade = 2)	vs. KL grade = 0, 1	1.22	0.77–1.92	0.404
Presence of KOA (KL grade≥ 3)	vs. KL grade = 0, 1	1.89	1.14–3.10	0.013**
Age (years)	+1 year	1.06	1.03–1.14	<0.001***
Gender	1: men, 0: women	5.55	3.57–8.63	<0.001***
Region	0: mountainous area, 1: coastal area	0.88	0.60–1.29	0.522
BMI (kg/m^2)	+1 kg/m^2	1.08	1.02–1.14	0.008**
Smoking	0: ex or never smoker, 1: current smoker	1.59	1.00–2.55	0.052
Alcohol consumption	0: ex or never drinker, 1: current drinker	0.81	0.54–1.21	0.298

DISH diffuse idiopathic skeletal hyperostosis, *BMI* body mass index, *LS* lumbar spondylosis, *KOA* knee osteoarthritis, *KL grade* Kellgren-Lawrence grade

OR odds ratios, *95 % CI* 95 % confidence interval

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

in women, and the most common site was the thoracic vertebrae. Presence of DISH was significantly associated with the presence of KOA and LS, after adjusting for potential associated factors.

There have been several epidemiologic studies on DISH in many parts of the world [12–19]. The results indicate that DISH is observed mainly in men and the elderly; prevalence increases with age, and it is distributed mostly in the thoracic spine. These results are supported by the results of the present study. However, there are considerable differences in the prevalence. Weinfeld et al. [20] reported that genetic or hereditary differences are important predisposing factors for DISH. Their previous study involved patients from ethnic populations, including 667 white, 144 black, 72 Native American, 11 Hispanic, and 30 Asian patients. They showed that the Asian, black, and Native American populations had a remarkably lower prevalence of DISH; however, their study population was small. In a recent study, Kim et al. [18] reported that race influences the prevalence of DISH. Their prevalence of DISH was 5.4 % in men and 0.8 % in women aged over 80 years in a Korean population, which is remarkably lower than the prevalence in our study, despite the similar race. Our prevalence was similarly high as the white population in Weinfield's report. Therefore, it is believed that genetic factors influence the prevalence of DISH more than race.

The present study clarified that most cases of DISH were observed in the thoracic vertebrae. There were no cases of DISH located in only the cervical or lumbar region. All cases of DISH in the cervical region were categorised as diffuse-type. Even if subjects were categorised into diffuse-type DISH, thoracic vertebrae were found to be the most affected. In addition, among the thoracic vertebrae, we found the predilection site to be the middle thoracic vertebrae (Th7–Th9). Holton et al. [27] reported that the distribution of the lowest level of DISH in 298 male subjects aged $\geq$65 years was 38 % in the thoracic region, 49 % in the thoracolumbar region, and 13 % in the lumbar region. It is interesting that DISH has predilection sites, which might be due to anatomic alignment of the vertebrae. For example, the middle thoracic vertebrae are likely to be affected by compressive mechanical stress because the Th8 is located nearly at the top in physiologic kyphosis. DISH originates mainly from the thoracic spine and extends to the cervical and/or lumbar spine by mechanical stress. In the present cross-sectional study, we could not evaluate whether DISH tends to occur in the thoracic vertebrae and then forms in the lumbar spine secondarily; however, we were able to follow-up on the ROAD study and clarify the disease course of thoracic DISH.

Regarding the definition of DISH, it might be easy to imagine that LS, defined by KL2 (defined as radiographically definite osteophytes), is associated with DISH. However, there are few reports to confirm the association between DISH and severe LS with the criterion of KL3 or 4. In the present study, we confirmed the significant association between DISH and LS, not only with the criterion of KL2, but also with KL $\geq$3. In addition, there are few reports to clarify the association between DISH and OA of other sites. In the present study, we also confirmed the significant association between DISH and KOA. In fact, the OR of the presence of DISH for KOA significantly increased according to the severity of KOA. The effects of LS and KOA coexisted independently. This result suggests that DISH and OA might be in a similar vein of disease, for example, the so-called 'bone proliferative group'. There have been several reports regarding the association between DISH and OPLL [4–7]. Resnick et al. [4] described 4 patients with coexisting DISH and cervical OPLL, and found OPLL in 50 % of 74 additional patients with DISH after reviewing their cervical spine radiographs. However, there has been no report on the association of DISH and OA; thus the etiology of ossification might not be similar to that of OA. Therefore, with only the results of the present study, we cannot definitely claim that DISH and OA are in a similar disease group, even though DISH tends to have similar associated factors, such as age, overweight (bigger BMI), and mechanical stress, as OA.

Another hypothesis is that there might be hidden associated factors that might affect both DISH and OA. We considered risk factors for metabolic syndrome as potential confounders. Several constitutional and metabolic abnormalities have been reported to be associated with DISH including obesity, large waist circumference, hypertension, diabetes mellitus, hyperinsulinemia, dyslipidemia, and hyperuricemia [21, 28–30]. In addition, both LS and KOA are well known to be associated with obesity [31]. We have already reported on the presence of hypertension and impaired glucose tolerance, and shown that the accumulation of metabolic risk factors is associated with the presence and occurrence of KOA [32, 33]. In addition, we found that current smoking, a known risk factor for cardiovascular disease as well as metabolic risk factors, was significantly associated with DISH. These findings may indicate that DISH is a candidate surrogate index for metabolic risk factors as a predictor of OA, or vice versa. We could not evaluate this hypothesis at present, but we would clarify the association including the causal relationships between DISH, OA, and metabolic risk factors in a further study.

Alternatively, we considered associated factors for inflammation or cartilage metabolic turnover as potential confounders between DISH and OA. These factors might coexist as risk factors for DISH and OA. Thus, there might be a direct or indirect pathway between DISH and OA via hidden associated factors, which should be investigated in a further study.

This study has several limitations. First, although the ROAD study includes a large number of participants, these subjects may not truly represent the general population. To address this, we compared the anthropometric measurements and frequencies of smoking and alcohol consumption between study participants and the general Japanese population; no significant differences were found, with the exception that male ROAD study participants aged 70–74 years were significantly smaller in terms of body structure than the overall Japanese population ($p < 0.05$)

[25]. This difference should be considered when evaluating potential risk factors in men aged 70–74 years; factors such as body build, particularly greater weight, are known to be associated with LS and KOA. Therefore, our results may be an underestimation of the prevalence of these conditions. Second, in the present study, we used only the data of the baseline study. Thus, we were not able to confirm a causal relationship between DISH status and other associated factors, as mentioned above. Nevertheless, we have performed a follow-up study, so we will be able to clarify the causal relationship between DISH status and OA in the near future. Third, this study could not evaluate the cervicothoracic junction (C7–Th4) because we assessed only radiographs. Although most cases of DISH existed in the inferior thoracic spine, as Fig. 2 shows, the lack of findings in the C7/C1–Th3/Th4 levels might have underestimated the prevalence of DISH. To evaluate the cervicothoracic junction, it would be necessary to use computed tomography or magnetic resonance imaging of the whole spine, which appeared impossible to perform on more than 1,600 subjects. Fourth, LS defined by KL2 may have been included in cases of DISH, but there is no method to confirm the overlap of the presence of DISH and LS of KL2 using the radiographic diagnostic criteria. DISH is observed mainly in the thoracic region, and only the diffuse type expands partly into the lumbar region. Therefore, there is a small possibility that LS of KL2 might be contaminated into DISH. Finally, in the present study, we could not evaluate other sites of OA besides the knee and lumbar spine, such as the hands or hip. To evaluate DISH and other sites of OA, we should evaluate the presence or occurrence of OA at other sites in a further study.

In conclusion, in the present population-based study, we found that the prevalence of DISH was 10.8 % in the overall population. Prevalence was significantly higher in older subjects, and mainly distributed at the thoracic spine. Logistic regression analysis revealed that the presence of DISH was significantly associated with older age, male sex, higher BMI, and presence of severe KOA.

Acknowledgments This work was supported by Grants-in-Aid for Scientific Research B23390172 and B20390182 to NY, C20591737 to TA, and C20591774 to SM, for Young Scientists A18689031 to HO, and Collaborating Research with NSF 08033011-00262 (Director, NY) from the Ministry of Education, Culture, Sports, Science and Technology; and H17-Men-eki-009 (Director, KN), H18-Choujyu-037 (Director, TN), H20-Choujyu-009 (Director, NY), H23-Chojyu-002 (Director, TA), and H25-Chojyu-007 (Director, NY) from the Ministry of Health, Labour and Welfare in Japan. This study also was supported by grants from the Japan Osteoporosis Society (NY, SM, HO, and TA) and research aid from the Japanese Orthopaedic Association (JOA-Subsidized Science Project Research 2006-1 and 2010-2 [Director, HK]). The authors wish to thank Dr. Takako Nojiri and Mr. Kazuhiro Hatanaka of the Gobo Public Health Centre; Dr. Naoki Hirabayashi of the Kawakami Clinic, Hidakagawa Town; Mrs. Tomoko Takijiri, Mrs. Kumiko Shinou, Mrs. Rie Takiguchi, Mrs. Kyoko Maeda, Ms. Ikuyo Ueyama, Mrs. Michiko Mori, Mrs. Hisayo Sugimoto, and other members of the public office in Hidakagawa Town; Dr. Shinji Matsuda of the Shingu Public Health Centre; and Mrs. Tamako Tsutsumi, Mrs. Kanami Maeda, Mr. Shoichi Shimoichi, Mrs. Megumi Takino, Mrs. Shuko Okada, Mrs. Kazuyo Setoh, Mrs. Chise Ryouno, Mrs. Miki Shimosaki, Mrs. Chika Yamaguchi, Mrs. Yuki Shimoji, and other members of the public office in Taiji Town for their assistance in locating and scheduling participants for examinations. We also thank Ms. Kyoko Yoshimura, Mrs. Toki Sakurai, and Mrs. Saeko Sahara for their assistance with data reduction and administration.

Conflict of interest All authors declare that (1) no author has received corporate support for the submitted work; (2) the authors have no relationships with companies that might have an interest in the submitted work in the previous 3 years; (3) the authors' spouses, partners, or children do not have financial relationships that may be relevant to the submitted work; and (4) the authors have no nonfinancial interests that may be relevant to the submitted work.

References

1. Mader R, Sarzi-Puttini P, Atzeni F, Olivieri I, Pappone N, Verlaan JJ, Buskila D (2009) Extraspinal manifestations of diffuse idiopathic skeletal hyperostosis. Rheumatology (Oxford) 48: 1478–1481
2. Resnick D, Niwayama G (1976) Radiographic and pathologic features of spinal involvement in diffuse idiopathic skeletal hyperostosis (DISH). Radiology 119:559–568
3. Mata S, Chhem RK, Fortin PR, Joseph L, Esdaile JM (1998) Comprehensive radiographic evaluation of diffuse idiopathic skeletal hyperostosis: development and interrater reliability of a scoring system. Semin Arthr Rheum 28:88–96
4. Resnick D, Guerra J Jr, Robinson CA, Vint VC (1978) Association of diffuse idiopathic skeletal hyperostosis (DISH) and calcification and ossification of the posterior longitudinal ligament. AJR 131:1049–1053
5. Ono M, Russell WJ, Kudo S, Kuroiwa Y, Takamori M, Motomura S, Murakami J (1982) Ossification of the thoracic posterior longitudinal ligament in a fixed population. Radiological and neurological manifestations. Radiology 143:469–474
6. Ehara S, Shimamura T, Nakamura R, Yamazaki K (1998) Paravertebral ligamentous ossification: DISH, OPLL and OLF. Eur J Radiol 27:196–205
7. Yoshimura N, Nagata K, Muraki S, Oka H, Yoshida M, Enyo Y, Kagotani R, Hashizume H, Yamada H, Ishimoto Y, Teraguchi M, Tanaka S, Kawaguchi H, Toyama Y, Nakamura K, Akune T (2013) Prevalence and progression of radiographic ossification of the posterior longitudinal ligament and its associated factors in the Japanese population: a 3-year follow-up of the ROAD study. Osteoporos Int [E-pub ahead of print]
8. Hannallah D, White AP, Goldberg G (2007) Diffuse idiopathic skeletal hyperostosis. Oper Tech Orthop 17:174–177
9. Albert TJ, Mader R (2002) Clinical manifestations of diffuse idiopathic skeletal hyperostosis of the cervical spine. Semin Arthr Rheum 32:130–135
10. Meyer PR Jr (1999) Diffuse idiopathic skeletal hyperostosis in the cervical spine. Clin Orthop Relat Res 359:49–57
11. Westerveld LA, Verlaan JJ, Oner FC (2009) Spinal fractures in patients with ankylosing spinal disorders: a systematic review of the literature on treatment, neurological status and complications. Eur Spine J 18:145–156
12. Hendrix RW, Melany M, Miller F, Rogers LF (1994) Fracture of the spine in patients with ankylosis due to diffuse skeletal hyperostosis: clinical and imaging findings. AJR 162:899–904

13. Julkunen H, Heinonen OP, Knekt P, Maatela J (1975) The epidemiology of hyperostosis of the spine together with its symptoms and related mortality in a general population. Scand J Rheumatol 4:23–27
14. Tsukamoto Y, Onitsuka H, Lee K (1977) Radiological aspects of DISH in the spine. AJR 129:913–918
15. Bloom RA (1984) The prevalence of ankylosing hyperostosis in a Jerusalem population–with description of a method of grading the extent of the disease. Scand J Rheumatol 13:181–189
16. Cassim B, Mody G, Rubin D (1990) The prevalence of diffuse idiopathic skeletal hyperostosis in African blacks. Br J Rheumatol 29:131–132
17. Kiss C, O'Neill TW, Mituszova M, Szilagyi M, Donath J, Poor GY (2002) Prevalence of diffuse idiopathic skeletal hyperostosis in Budapest, Hungary. Rheumatology 41:1335–1336
18. Kim SK, Choi BR, Kim CG, Chung SH, Choe JY, Joo KB, Bae SC, Yoo DH, Jun JB (2004) The prevalence of diffuse idiopathic skeletal hyperostosis in Korea. J Rheumatol 31:2032–2035
19. Kiss C, O'Neill TW, Mituszova M, Szilagyi M, Poor G (2002) The prevalence of diffuse idiopathic skeletal hyperostosis in a population-based study in Hungary. Scand J Rheumatol 31:226–229
20. Weinfeld RM, Olson PN, Maki DD, Griffiths HJ (1997) The prevalence of diffuse idiopathic skeletal hyperostosis (DISH) in two large American Midwest metropolitan hospital populations. Skeletal Radiol 26:222–225
21. Kiss C, Szilagyi M, Paksy A, Poor G (2002) Risk factors for diffuse idiopathic skeletal hyperostosis: a case control study. Rheumatology (Oxford) 41:27–30
22. Mader R, Novofestovski I, Adawi M, Lavi I (2009) Metabolic syndrome and cardiovascular risk in patients with diffuse idiopathic skeletal hyperostosis. Semin Arthr Rheum 38:361–365
23. Kellgren JH, Lawrence LS (1957) Radiological assessment of osteoarthrosis. Ann Rheum Dis 16:494–502
24. Yoshimura N, Muraki S, Oka H, Kawaguchi H, Nakamura K, Akune T (2010) Cohort profile: research on osteoarthritis/osteoporosis against disability (ROAD) study. Int J Epidemiol 39:988–995
25. Yoshimura N, Muraki S, Oka H, Mabuchi A, En-yo Y, Yoshida M, Saika A, Yoshida H, Suzuki T, Yamamoto S, Ishibashi H, Kawaguchi H, Nakamura K, Akune T (2009) Prevalence of knee osteoarthritis, lumbar spondylosis, and osteoporosis in Japanese men and women: the research on osteoarthritis/osteoporosis against disability study. J Bone Miner Metab 27:620–628
26. Orwoll E, Blank JB, Barrett-Connor E, Cauley J, Cummings S, Ensrud K, Lewis C, Cawthon PM, Marcus R, Marshall LM, McGowan J, Phipps K, Sherman S, Stefanick ML, Stone K (2005) Design and baseline characteristics of the osteoporotic fractures in men (MrOS) study–a large observational study of the determinants of fracture in older men. Contemp Clin Trials 26:569–585
27. Holton KF, Denard PJ, Yoo JU, Kado DM, Barrett-Connor E, Marshall LM, Osteoporotic Fractures in Men (MrOS) Study Group (2011) Diffuse idiopathic skeletal hyperostosis and its relation to back pain among older men: the MrOS Study. Semin Arthr Rheum 41:131–138
28. Littlejohn GO (1985) Insulin and new bone formation in diffuse idiopathic skeletal hyperostosis. Clin Rheumatol 4:294–300
29. Denko CW, Boja B, Moskowitz RW (1994) Growth promoting peptides in osteoarthritis and diffuse idiopathic skeletal hyperostosis–insulin, insulin-like growth factor-I, growth hormone. J Rheumatol 21:1725–1730
30. Vezyroglou G, Mitropoulos A, Kyriazis N, Antoniadis C (1996) A metabolic syndrome in diffuse idiopathic skeletal hyperostosis: a controlled study. J Rheumatol 23:672–676
31. Muraki S, Akune T, Oka H, Mabuchi A, En-yo Y, Yoshida M, Saika A, Nakamura K, Kawaguchi H, Yoshimura N (2009) Association of occupational activity with radiographic knee osteoarthritis and lumbar spondylosis in elderly patients of population-based cohorts: a large-scale population-based study. Arthr Care Res 61:779–786
32. Yoshimura N, Muraki S, Oka H, Kawaguchi H, Nakamura K, Akune T (2011) Association of knee osteoarthritis with the accumulation of metabolic risk factors such as overweight, hypertension, dyslipidemia, and impaired glucose tolerance in Japanese men and women: the ROAD study. J Rheumtol 38:921–930
33. Yoshimura N, Muraki S, Oka H, Tanaka S, Kawaguchi H, Nakamura K, Akune T (2012) Accumulation of metabolic risk factors such as overweight, hypertension, dyslipidemia, and impaired glucose tolerance raises the risk of occurrence and progression of knee osteoarthritis: a 3-year follow-up of the ROAD study. Osteoarthr Cartil 20:1217–1226

J Orthop Sci
DOI 10.1007/s00776-014-0677-1

ORIGINAL ARTICLE

Improved accuracy of diagnosis of lumbar intra and/or extra-foraminal stenosis by use of three-dimensional MR imaging: comparison with conventional MR imaging

Hiroshi Yamada · Masaki Terada · Hiroshi Iwasaki · Toru Endo · Motohiro Okada · Shinichi Nakao · Hiroshi Hashizume · Akihito Minamide · Yukihiro Nakagawa · Hideto Nishi · Syunji Tsutsui · Hiroyuki Oka · Munehito Yoshida

Received: 9 July 2014 / Accepted: 19 November 2014

Abstract
Background The purposes of this study were to assess the reliability of 3-dimensional magnetic resonance (MR) imaging (3D MRI) and conventional MRI (CMRI) for detection of lumbar intra and/or extra-foraminal stenosis (LIEFS) and to compare the diagnostic accuracy of the 2 imaging modalities.
Methods A total of 60 sets of 3D MR and CMR images from 20 healthy volunteers and 40 LIEFS patients were qualitatively rated according to defined criteria by 3 independent, blinded readers. Kappa statistics were used to characterize intra and inter-reader reliability for qualitative rating of data. Multireader, multicase analysis was used to compare lumbar foraminal stenosis detection between the 2 modalities.
Results Intra-reader agreement for 3D MRI was excellent, with kappa = 0.90; that for CMRI was good, with kappa = 0.78. Average inter-reader agreement for 3D MRI was good, with kappa = 0.79, whereas that for CMRI was moderate, with kappa = 0.41. Average area under the ROC curve values (1st reading/2nd reading) for detection of lumbar foraminal stenosis using 3D MRI and CMRI were 0.99/0.99 and 0.94/0.92, respectively. Detection of LIEFS with 3D MRI was significantly better than with CMRI ($P = 0.0408/0.0294$).
Conclusions These results suggest that CMRI was of limited use for detection of the presence of LIEFS. Isolated imaging with CMRI may risk overlooking the presence of LIEFS. In contrast, reliability of 3D MRI for detection of LIEFS was good. Furthermore, readers' performance in the diagnosis of LIEFS can be improved by use of 3D MRI. Therefore, 3D MRI is recommended when using imaging for diagnosis of LIEFS.

H. Yamada (✉) · H. Iwasaki · T. Endo · M. Okada · S. Nakao · H. Hashizume · A. Minamide · Y. Nakagawa · H. Nishi · S. Tsutsui · M. Yoshida
Department of Orthopedic Surgery, Wakayama Medical University, 811-1 Kimiidera, Wakayama, Wakayama 641-8510, Japan
e-mail: yamacha@wakayama-med.ac.jp

M. Terada
Wamayama-Minami Radiology Clinic, Wakayama, Japan

H. Oka
Department of Medical Research and Management for Musculoskeletal Pain, 22nd Century Medical and Research Center, Graduate School of Medicine, The University of Tokyo, Bunkyō, Japan

Introduction

Most surgery for lumbar spinal stenosis is considered successful for relief of symptoms, but a significant number of failures occur. The term "failed back surgery syndrome" (FBSS) is used to designate persistent complaints of low back pain and/or leg pain among patients who have undergone surgical procedures intended to relieve those complaints. Burton et al. reported the most common reason for FBSS as failure to diagnose lateral spinal stenosis, which includes intra and/or extra-foraminal nerve root entrapment [1]. This diagnostic limitation seems to be the result of difficulty identifying the lesion outside the spinal canal with conventional imaging modalities [2]. When the site of nerve compression is peripheral to the root sleeves, myelography provides no information [3]. Therefore, parasagittal magnetic resonance (MR) images have long been the recommended method for investigation of any abnormality in the region of the intervertebral foramen. Obliteration of the perineural fat surrounding the nerve root has been reported to

Published online: 11 December 2014

be the finding most suggestive of lumbar intra and/or extraforaminal stenosis (LIEFS). However, such MR images do not give complete information and sometimes result in false-positive or false-negative findings [4, 5].

The advent of 3-dimensional magnetic resonance imaging (3D MRI) has rapidly countered this difficulty in recent years [6, 7]. Direct visualization of the nerve root in the intervertebral foramen by use of 3D MRI has been a great benefit in the daily practice of spinal medicine. Nerve abnormalities outside the spinal canal can be easily diagnosed by using this modality. However, no reference standard for diagnosis of LIEFS on 3D MRI has been established, and the diagnostic performance of 3D MRI and conventional imaging modalities has not yet been directly compared.

The purposes of this study were to propose new diagnostic criteria for LIEFS on 3D MRI, to assess the reliability of 3D MRI and conventional MRI (CMRI) for the identification of LIEFS, and to compare LIEFS detection between the 2 imaging modalities.

Materials and methods

Patient population

The local ethics committee approved this retrospective study. Informed consent was obtained from all study participants. To collect CMRI and 3D MRI data samples for this reading study, positive images (radiographically abnormal cases) were obtained from patients who underwent surgery for LIEFS at our university hospital. To achieve uniform reading conditions, the responsible lesions were limited to the L5-S1 level, which is the most common site of involvement of LIEFS. To establish a clear diagnosis, only cases involving a single stenotic lesion were selected. That is, the patients had no concomitant intraspinal canal lesion at the time of surgery. Their leg symptoms were completely resolved after L5 nerve block, and the outcome of decompression surgery for LIEFS at L5–S1 was successful. LIEFS images that were of low diagnostic quality for the examinations, because of motion or other artifacts were excluded. After reviewing all the images and records, the final study group with positive images comprised 40 patients (22 male, 18 female; age 50–84 years, mean 70.0 years). The study group for negative images (radiographically normal cases) consisted of 20 normal healthy volunteers (10 male, 10 female; age 18–28 years; mean 21.3 years). These subjects had no current or previous history of low back pain and/or leg pain and no history of spinal disorders, and their spinal MRI revealed no disc degeneration over the entire lumbar spine. Thus, a total of 60 sets of 3D MRI and CMRI images from 20 normal healthy volunteers and 40 LIEFS patients were evaluated.

Imaging technique

MRI was performed with a 3.0 T MR scanner (Achieva; Philips Medical Systems, Best, Netherlands) using a 32-channel SENSE-Torso/Cardiac coil. The sequences for 3D MRI are called "Proset Myelo" in this system (3D FFE with, in principle, the selective excitation technique). The scanner settings were: TR = 20 ms, TE = 8 ms, flip angle = 15 degrees, slice thickness = 0.55 mm, field of view = 240 mm, and matrix = 256 × 512. Images were then subjected to postprocessing with multiplanar reformatting in a workstation to provide continuous longitudinal nerve images. For the conventional MRI procedure, the spin echo sequences of sagittal T1-weighted images were: TR = 650 ms, TE = 10 ms, flip angle = 90°, field of view = 280 mm, and matrix = 352 × 512.

Imaging analysis

Images were provided to the readers on CDs and viewed with commercial software (Virtual Place Liberty; AZE, Japan). Display monitors were not standardized across readers. Qualitative ratings were performed according to defined criteria by 3 independent readers (orthopedic surgeons and board-certified spinal experts of the Japanese Orthopedic Association) with no knowledge of the patients' clinical information. Each reader attended a lecture explaining the standardized definitions of imaging features from the first author (H.Y.), and consensus for interpretation of 3D MRI and CMRI findings was obtained among the readers before the start of the study. The images were scored as "definitely showing LIEFS", "probably showing LIEFS", "probably not showing LIEFS", or "definitely not showing LIEFS". All 3D MRI and CMRI images were independently evaluated twice by the 3 readers with a 1-month interval between readings.

The following reference standards were used for each imaging modality. On CMRI, obliteration of the perineural fat surrounding the nerve root in the intervertebral foramen was taken into consideration (parasagittal MRI reading technique). If the perineural fat was clearly visible, the image was considered normal. If the perineural fat was diminished because of disc height loss, osteoarthritic changes in the facet joints, buckling of the ligamentum flavum, or protrusion of the annulus fibrosis, the image was considered abnormal [8].

No widely used diagnostic criterion or grading system exists for LIEFS on 3D MRI. Hence, the authors reviewed the images of all the surgical cases of LIEFS and selected 4 representative imaging features as an index of highly suspicious findings of LIEFS:

1. transverse path of the nerve root and/or spinal nerve (Fig. 1a);

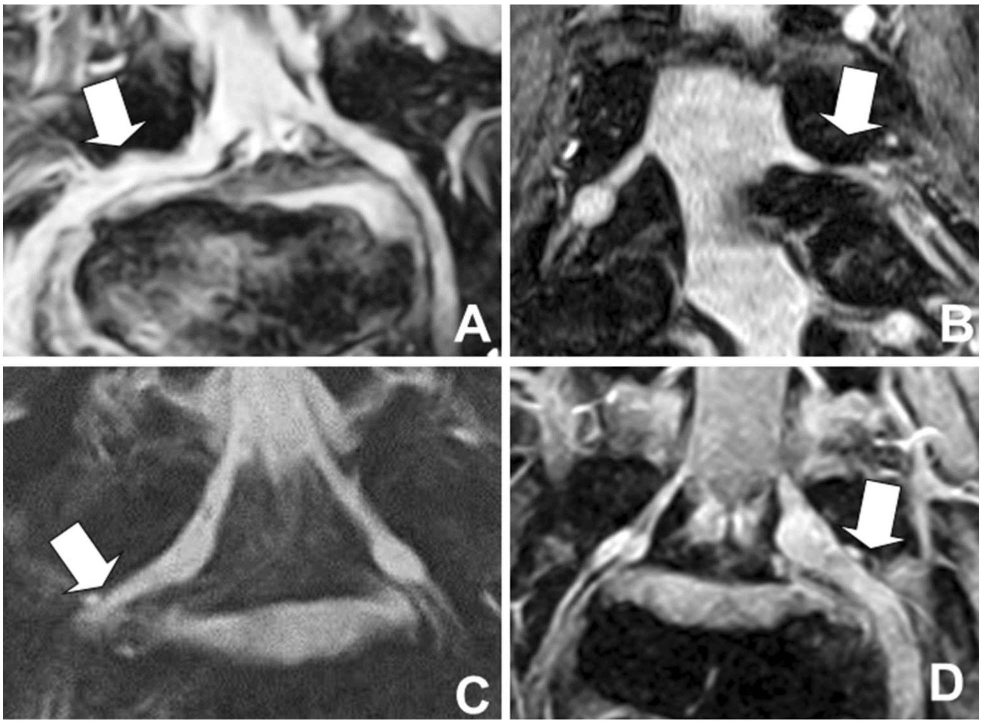

Fig. 1 Index of highly suspicious findings of LIEFS: **a** transverse path of the nerve root and spinal nerve, **b** obscurity of the spinal ganglion, **c** constriction of the spinal nerve, and **d** nerve swelling

2. obscurity of the dorsal root ganglion (DRG) (Fig. 1b);
3. spinal nerve indentation (Fig. 1c); and
4. nerve swelling (Fig. 1d).

These radiological findings on 3D MRI were highly consistent with the anatomical abnormalities in our surgical case series. Although all 4 radiological abnormalities were not always present on 3D MRI in cases with LIEFS, at least 1 imaging feature was always observed. Therefore, if any 1 of these 4 radiological findings was observed, it was regarded as abnormal. Images that did not have any of these radiological findings were considered normal.

As a basic step toward developing diagnostic criteria, we defined the area from the medial pedicle wall to the lateral pedicle wall as the intra-foraminal zone and the area beyond the lateral pedicle wall as the extra-foraminal zone. The spindle-shaped nerve root in the intra and/or extra-foraminal zone was defined as the DRG. The nerve root in the extra-foraminal zone beyond the DRG was defined as the spinal nerve. The nerve between the thecal sac and the DRG was defined as the nerve root [9]. Imaging features and their association with intraoperative findings were:

1. Transverse path of the nerve root and/or spinal nerve (Fig. 1a). The transverse path was defined as positive when either of the tilting angles of the nerve root and/or spinal nerve in the intra and/or extra-foraminal zone was larger than that of the normal contralateral side. The normal nerve root and spinal nerve basically run obliquely downward through the intervertebral foramina after branching from the dura mater. Hence, a transverse path is abnormal. The nerve root and/or spinal nerve were compressed and shifted upward by degenerating bulging discs. The transverse path of the nerve root and/or spinal nerve indicated the presence of up-down-type stenosis in the intra and/or extraforaminal zone [10, 11].
2. Obscurity of the DRG (Fig. 1b). Obscurity of the DRG was defined as positive when its configuration became unclear. DRGs are the largest neural structures around the intervertebral foramina and are ordinarily distinguishable from the nerve root and spinal nerve by their spindle shape on 3D MR images. Because the vast majority of DRGs are normally located in the intra-foraminal zone, morphological changes to the DRG imply significant diminishment of available space for the nerve root around the intervertebral foramen. Thus, when DRG configuration becomes unclear, the existence of LIEFS is strongly suspected. DRGs were compressed by degenerative bulging discs from the inferior and by superior articular facets from the posterior of the intra-foraminal zone. Obscurity of the DRG indicated circumferential-type stenosis in the intra-foraminal zone [4, 11].

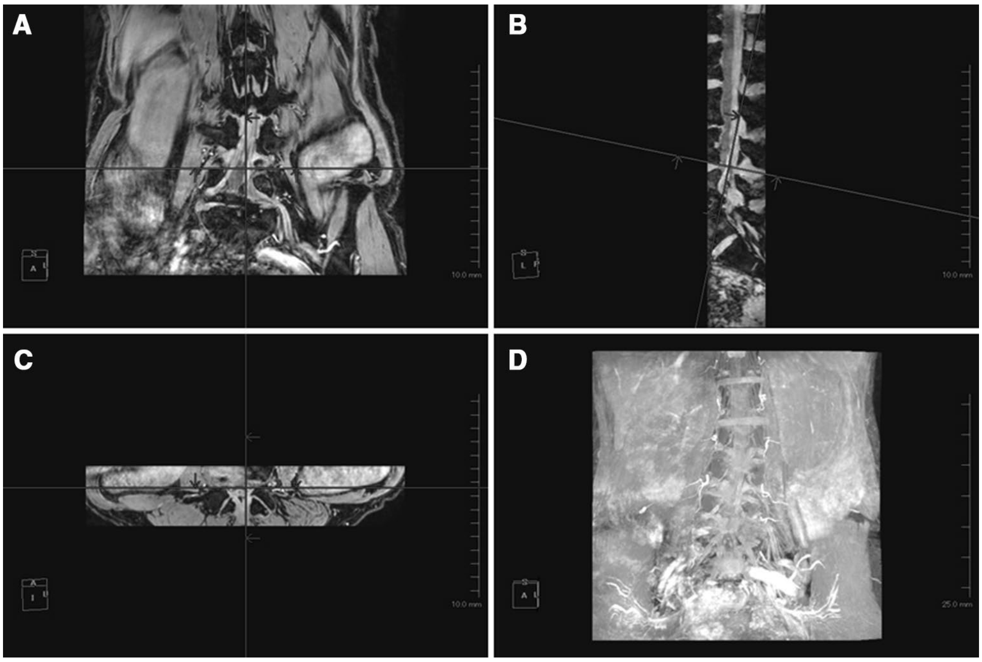

Fig. 2 An example of the 3D view of the 5th lumbar nerve roots and spinal nerves using MPR (multi-planar reconstruction) in **a** coronal view, **b** axial view, **c** sagittal view and the MIP (maximum intensity projection) technique (**d**)

3. Spinal nerve indentation (Fig. 1c). Spinal nerve indentation was regarded as positive when the nerve diameter narrowed locally. Because the nerve thickness is the same other than at the dorsal root ganglion, indentation is evidence suggesting the presence of stenosis. Spinal nerve indentation indicated spinal nerve entrapment on operative findings, which was mainly observed in cases of extra-foraminal stenosis at the lumbosacral junction. This lesion had several etiologies, for example impingement of the transverse process of L5 against the ala of the sacrum [12], entrapment by the lumbosacral ligament [13, 14], and entrapment by osteophytes of the L5 vertebral bodies and sacral ala [15]. All these lesions occurred in the lumbosacral tunnel [16] in the extra-foraminal zone. The lumbosacral tunnel is an osteofibrotic tunnel for the exiting nerve of L5, which is formed by developing osteophytes and the degenerating hypertrophied lumbosacral ligament. This unique anatomical structure contributed to spinal nerve entrapment.
4. Nerve swelling (Fig. 1d). Swelling of the nerve root, DRG, or spinal nerve was defined as positive when the size of any of these structures exceeded that of the normal contralateral side. Although morphological changes to the nerve do not always indicate symptomatic radiculopathy, nerve swelling has been reported as a good indicator of symptomatic LIEFS in previous studies [7]. Thus, the existence of nerve swelling at any level from the entrance zone to the extraforaminal zone and at any range from local to total was considered abnormal. This finding was often observed in cases with clinical symptoms of severe spontaneous pain. Thus, nerve swelling may indicate the existence of nerve inflammation.

An example of the 3D view of the 5th lumbar nerve roots and spinal nerves using multi-planar reconstruction and the maximum intensity projection technique is shown in Fig. 2. The readers could observe many different views of the nerves by adjusting the screen to detect the intra and/or extra-foraminal lesion.

Statistical methods

First, reliability was measured by use of kappa statistics. This statistical analysis was performed by using JMP version 10 (SAS Institute Japan, Tokyo, Japan). Intra and inter-reader reliability was assessed with the kappa coefficient, which was characterized as: <0.0 = "poor" agreement, 0.0–0.2 = "slight" agreement beyond chance, 0.21–0.4 = "fair" agreement, 0.41–0.60 = "moderate" agreement, 0.61–0.80 = "substantial" agreement, and 0.81–1.00 = "almost perfect" agreement [17]. To analyze the data obtained, readers' ratings were classified into 2 categories: "positive," consisting of definite or probable LIEFS, and "negative," consisting of cases defined as probably or definitely not showing LIEFS. Second, to compare the diagnostic performance of the 2 imaging modalities, receiver operating characteristic (ROC) analysis based on a sequential test method was used [18, 19]. To analyze the data, readers' ratings were converted into a numerical rating scale as follows: "definitely showing LIEFS" = 4, "probably showing LIEFS" = 3, "probably not showing LIEFS" = 2, and "definitely not showing LIEFS" = 1. The area under the ROC curve (AUC) and 95 % confidence intervals (CI) were obtained with a quasi-maximum likelihood estimation of binomial distribution by using DBM MRMC software (version 2.2). Accuracy was determined by using the AUC. An area of 1 represents a perfect test; an area of 0.5 represents a worthless test. An approximately guide for classifying the accuracy of a diagnostic test is the traditional academic point system, with AUC values 0.90–1 = "excellent", 0.80–0.90 = "good", 0.70–0.80 = "fair", 0.60–0.70 = "poor", and 0.50–0.60 = "fail" [20]. The significance of the different AUC for CMRI and 3D MRI was tested by use of the Dorfman–Berbaum–Metz method, which included both reader variation and case sample variation, by means of an analysis of variance approach. P values <0.05 were regarded as indicative of a significant difference.

Results

The first and second reading results of each reader are summarized in Table 1. Average sensitivity and specificity for 3D MRI (1st reading/2nd reading) were 85.8/90.0 and 98.3/98.3 %, respectively. Those for CMRI were 59.2/63.3 and 100/100 %, respectively. Intra-reader reliability for CMRI and 3D MRI is summarized in Table 2. Intra-reader reliability for 3D MRI showed agreement was excellent, with kappa = 0.90, whereas agreement for CMRI was good, with kappa = 0.78. Inter-reader reliability for CMRI and 3D MRI are summarized in Tables 3 and 4, respectively. Inter-reader agreement for 3D MRI was good, with kappa = 0.79, whereas agreement for CMRI was moderate, with kappa = 0.41. The AUC values of the ROC curves for 3D MRI and CMRI for individual observers are summarized in Table 5. The mean AUC of the ROC curves (1st reading/2nd reading) for the 3 observers was 0.99/0.99 for 3D MRI and 0.94/0.92 for CMRI (Figs. 3, 4). AUC values for the 2 imaging modalities were statistically significantly different (P = 0.0408/0.0294, 95 % CI 0.10009–0.00178/0.00803–0.11867).

Table 1 Sensitivity and specificity of CMRI and 3D MRI for individual observers

Statistic and reader	3D MRI (1st reading/2nd reading)	CMRI (1st reading/2nd reading)
Sensitivity (TP/TP + FN) (%)		
A	82.5/82.5	70.0/67.5
B	82.5/92.5	70.0/57.5
C	92.5/95.0	37.5/65.0
Average	85.8/90.0	59.2/63.3
Specificity (TN/TN + FP) (%)		
A	100/95.0	100/100
B	95.0/100	100/100
C	100/100	100/100
Average	98.3/98.3	100/100

TP indicates true positive, *FN* false negative, *TN* true negative, *FN* false negative

Table 2 Intra-reader reliability of CMRI and 3D MRI for individual observers

Imaging modality and observer	κ Statistic	Standard error	Agreement
3D MRI			
A	0.8986	0.1291	58
B	0.8275	0.1291	55
C	0.9644	0.1291	59
Average	0.8968		
CMRI			
A	0.8661	0.1291	57
B	0.6089	0.1291	49
C	0.8636	0.1291	57
Average	0.7795		

Table 3 Inter-observer reliability of 3D MRI

Observers	κ Statistic	Standard error	Agreement
1st reading			
A and B	0.3114	0.1291	41
A and C	0.3407	0.1291	42
B and C	0.4139	0.1291	45
2nd reading			
A and B	0.5567	0.1291	47
A and C	0.3407	0.1291	42
B and C	0.4920	0.1291	47
Average	0.4092		

Discussion

Failure to diagnose LIEFS continues to be the most common reason for FBSS [1]. The difficulty in identifying LIEFS with conventional imaging modalities is well-recognized. LIEFS tends to be overlooked rather than overestimated. Therefore, new imaging techniques to detect LIEFS with certainty are required.

Table 4 Inter-observer reliability of CMRI

Observers	κ Statistic	Standard error	Agreement
1st reading			
A and B	0.7634	0.1291	53
A and C	0.7943	0.1291	54
B and C	0.7586	0.1291	53
2nd reading			
A and B	0.7586	0.1291	53
A and C	0.7917	0.1291	54
B and C	0.8933	0.1291	57
Average	0.7933		

Table 5 AUC values of the ROC curves for 3D MRI and CMRI for individual observers

Reader	3D MRI (1st reading/2nd reading)	CMRI (1st reading/2nd reading)
A	1.00/0.98	0.96/0.92
B	0.96/1.00	0.91/0.96
C	1.00/0.99	0.93/0.89
Average	0.99/0.99	0.94/0.92

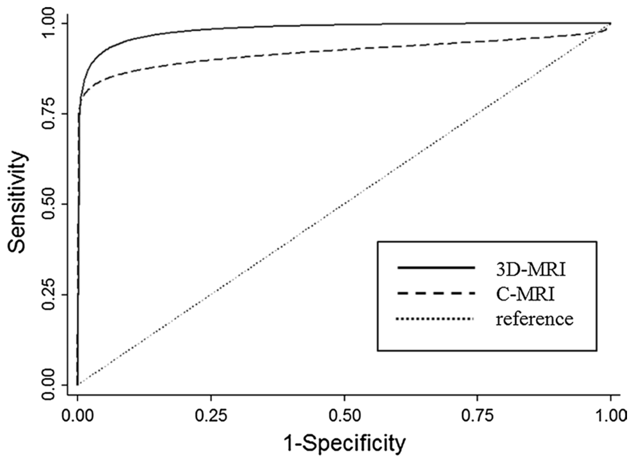

Fig. 3 Averaged ROC curves for 3 observers obtained from 1st reading results for 3D MRI and CMRI

This study confirms the low reliability of the parasagittal MRI reading technique for evaluating LIEFS reported in the past. Speciciale et al. [21] reported the lowest overall inter-observer reliability kappa value, 0.26, for ratings of stenosis severity, which included both foraminal and lateral recess and central stenosis. Lurie et al. [8] reported good agreement for intra-reader reliability for foraminal stenosis, with an overall kappa of 0.77, but moderate agreement for inter-reader reliability, with an overall kappa of 0.58. Our study also revealed good agreement for intra-reader reliability and moderate agreement for inter-reader reliability, with overall kappa values of 0.78 and 0.41, respectively. Taking these findings into account, we conclude that parasagittal MRI reading of CMRI is not highly reliable for detection of LIEFS, especially with regard to inter-reader agreement. This situation is not ideal when considering surgical indications for LIEFS. Presurgical diagnosis may differ with different examiners, which may increase the number of FBSS patients.

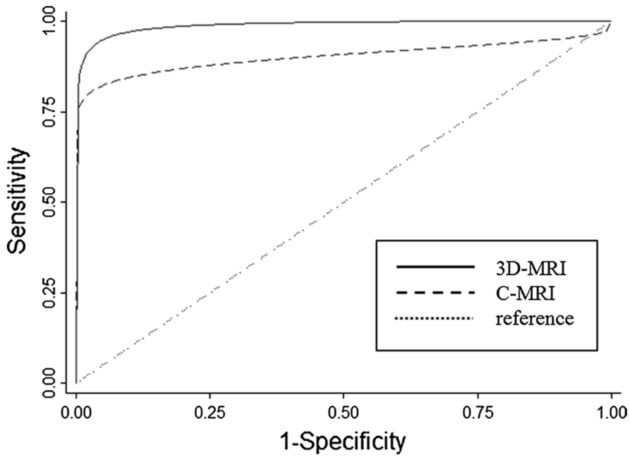

Fig. 4 Averaged ROC curves for 3 observers obtained from 2nd reading results for 3D MRI and CMRI

The lower reliability of the parasagittal MRI reading technique for LIEFS identification has several possible causes. Evaluating a limited number of cross-sectional images is not sufficient to identify all abnormalities along the nerve pathways. This technique is limited to evaluation of foraminal stenosis and is inadequate for investigating extraforaminal pathology. Furthermore, accurate evaluation of nerve pathology in intra and/or extraforaminal zones where the nerve pathways progress in 3 dimensions is beyond the ability of 2-dimensional conventional imaging interpretation.

From this perspective, 3D MRI seems ideal for evaluating nerve lesions around the intervertebral foramen. Direct visualization of nerve morphology is very helpful for identifying nerve abnormalities with high reliability. As expected, this new imaging modality resulted in excellent agreement for intra-reader reliability, with overall kappa of 0.90, and good agreement for inter-reader reliability, with overall kappa of 0.79. In addition to improved imaging quality with high spatial resolution, we believe our diagnostic criteria for LIEFS on 3D MRI contributed to readers' understanding of the nerve pathology in the intra and/or extra-foraminal zone and served as a support tool for more reliable identification of nerve lesions.

No study comparing diagnostic performance between 3D MRI and CMRI using ROC analysis has been conducted to date. ROC analysis is a crucial technique for evaluating diagnostic systems, and ROC curves have been regarded as imperative when comparing new imaging technology [22, 23]. Our study demonstrated that the AUC values of both imaging modalities were greater than 0.9, indicative of excellent diagnostic performance in clinical use, but the AUC of 3D MRI was significantly higher than that of CMRI. This result suggests that the detectability of LIEFS by 3D MRI is superior to that by CMRI. Although direct comparison of diagnostic performance between 3D MRI and conventional imaging studies has not been conducted previously, this study demonstrated that 3D MRI is superior to CMRI in reliability and detectability.

This study has some limitations. First, the number of imaging samples was small, but a significant difference was observed between 3D MRI and CMRI with regard to reliability and detectability. Second, this study only focused on comparing the detectability of abnormal morphology by the 2 imaging modalities. Therefore, we recruited control subjects with little or no degenerative changes for negative images (radiographically normal cases), whereas the study group for positive images was recruited from patients who had LIEFS surgery. LIEFS may be more difficult to distinguish radiologically from age-related changes, and future studies should examine the sensitivity and specificity of these changes for an age-matched control group.

Investigating the percentage of symptomatic nerve roots that are correctly identified as having these 3D MRI abnormalities is also very important. Several reports have indicated that abnormal CMRI findings of lumbar disc herniation or spinal stenosis are not always accompanied by symptoms [24, 25]. Radiographic abnormalities of the nerve are common, but symptomatic nerves are less prevalent. Therefore, the correlation between 3D MRI abnormalities and clinical symptoms must be investigated further. Otherwise, overdiagnosis may occur. To resolve this problem, functional diagnosis with use of selective nerve blocking, electromyographical study [26, 27], and diffusion MRI [28] may be help to improve the specificity of diagnosing symptomatic LIEFS. Nonetheless, improving the detectability of radiographic abnormalities indicative of LEIFS is important in daily spinal practice. Not all screening tests have been shown to benefit the person being screened; however, finding unrecognized LIEFS would be very beneficial for patients who are scheduled for nerve decompression surgery because misdiagnosis of LIEFS remains one of main reasons for FBSS.

In conclusion, CMRI demonstrated limitations in identifying the presence of LIEFS, and isolated imaging by use of CMRI may risk overlooking the presence of LIEFS. In contrast, use of 3D MRI for diagnosis of LIEFS resulted in good reliability and detectability. Our new diagnostic criteria for LIEFS on 3D MRI enable reliable discrimination between a normal root and LIEFS. This study demonstrated that reader performance in diagnosis of LIEFS can be improved by use of 3D MRI. Therefore, 3D MRI is recommenced when using imaging for diagnosis of LIEFS.

Acknowledgments The authors wish to thank Dr Hiroko Ihara, Dr Misato Okouchi, and Mr Yuji Nakao in Wakayama-minami radiology clinic for their technical assistance and for collecting data, and Dr Junji Shiraishi in School of Health Sciences, Kumamoto University for his comment on the study design and interpretation of the data.

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Burton R, Kirkaldy-Willis W, Yong-Hing K, Heithoff K. Causes of failure of surgery on the lumbar spine. Clin Ortop Relat Res. 1981;157:191–7.
2. MacNab I. Negative disc exploration: an analysis of the causes of nerve root involvement in sixty-eight patients. J Bone Joint Surg Am. 1971;53(5):891–903.
3. Kornberg M. Extreme lateral lumbar disc herniations. Spine. 1987;12(6):586–9.
4. Kunogi J, Hasue M. Diagnosis and operative treatment of intraforaminal and extraforaminal nerve root compression. Spine. 1991;16(11):1312–30.
5. Cramer GD, Cantu JA, Dorsett RD, Greenstein JS, McGregor M, Howe JE, Glenn WV. Dimension of the lumbar intervertebral foramina as determined from the sagittal plane magnetic resonance imaging scans of 95 normal subjects. J Manipulative Physiol Ther. 2003;26(3):160–70.
6. Taira G, Endo K, Ito K. Diagnosis of lumbar disc herniation by three-dimensional MRI. J Orthop Sci. 1998;3(1):18–26.
7. Aota Y, Niwa T, Yoshikawa K, Fujiwara A, Asada T, Saito T. Magnetic resonance imaging and magnetic resonance myelography in the presurgical diagnosis of lumbar foraminal stenosis. Spine. 2007;32(8):896–903.
8. Lurie JD, Tosteson AN, Tosteson TD, Carragee E, Carrino J, Kaiser J, Blanco Sequeiros RT, Lecomte AR, Grove MR, Pearson LH, Weinstein JN, Herzog R. Reliability of readings of magnetic resonance imaging features of lumbar spinal stenosis. Spine. 2008;33(14):1605–10.
9. Byun WM, Jang HW, Kim SW. Three-dimensional magnetic resonance rendering imaging of lumbosacral radiculography in the diagnosis of symptomatic extraforaminal disc herniation with or without foraminal extension. Spine. 2012;37(10):840–4.
10. Jenis LG, An HS. Spine update: lumbar foraminal stenosis. Spine. 2000;25(3):389–94.
11. Baba H, Uchida K, Maezawa Y, Furusawa N, Okumura Y, Imura S. Microsurgical nerve root canal widening without fusion for lumbosacral intervertebral foraminal stenosis: technical notes and early results. Spinal Cord. 1996;34:644–50.
12. Wiltse LL, Guyer RD, Spencer CW. Alar transverse process impingement of the L5 spinal nerve: the far-out syndrome. Spine. 1984;9(1):31–41.
13. Olsewski JM, Simmons EH, Kallen FC, Mendel FC. Evidence from cadavers suggestive of entrapment of fifth lumbar spinal nerves by lumbosacral ligaments. Spine. 1991;16(3):336–47.
14. Transfeldt EE, Robertson D, Bradfold DS. Ligaments of the lumbosacral spine and their role in possible extraforaminal spinal nerve entrapment and tethering. J Spinal Disord. 1992;6(6):507–12.

15. Matsumoto M, Chiba K, Nojiri K, Ishikawa M, Toyama Y, Nishikawa Y. Extraforaminal entrapment of the fifth lumbar spinal nerve by osteophytes of the lumbosacral spine. Spine. 2002;27(6):E169–73.
16. Nathan H, Weizenbluth M, Halperin N. The lumbosacral ligament (LSL), with special emphasis on the "lumbosacral tunnel" and the entrapment of the 5th lumbar nerve. Int Orthop. 1982;6(3):197–202.
17. Raininko R, Manninen H, Battie MC, Gibbons LE, Gill K, Fisher LD. Observer variability in the assessment of disc degeneration on magnetic resonance images of the lumbar and thoracic spine. Spine. 1995;20(9):1029–35.
18. Dorfman DD, Berbaum KS, Metz CE. Receiver operating characteristic rating analysis: generalization to the population of readers and patients with the jackknife method. Invest Radiol. 1992;27(9):723–31.
19. Hills SL, Berbaum KS, Metz CE. Recent developments in the Dorfman–Berbaum–Metz procedure for multireader ROC study analysis. Acta Radiol. 2008;15(5):647–61.
20. Hosmer DW, Lemeshow S. Assessing the fit of the model. In: Hosmer DW, Lemeshow S, editors. Applied logistic regression. 2nd ed. New York: Wiley; 2000. p. 143–202.
21. Speciale AC, Pietrobon R, Urban CW, Richardson WJ, Helms CA, Major N, Enterline D, Hey L, Haglund M, Turner DA. Observer variability in assessing lumbar spinal stenosis severity on magnetic resonance imaging and its relation to cross-sectional spinal canal area. Spine. 2002;27(10):1082–6.
22. Obuchowski NA. ROC analysis. Am J Roentgenol. 2005;184(2):364–72.
23. Gur D. Technology and practice assessment: in search of a "desirable" statement. Radiology. 2005;234(3):659–60.
24. Boden SD, Davis DO, Dina TS, Patronas NJ, Wiesel SW. Abnormal magnetic-resonance scans of the lumbar spine in asymptomatic subjects. A prospective investigation. J Bone Joint Surg Am. 1990;72(3):403–8.
25. Ishimoto Y, Yoshimura N, Muraki S, Yamada H, Nagata K, Hashizume H, Takiguchi N, Minamide A, Oka H, Kawaguchi H, Nakamura K, Akune T, Yoshida M. Associations between radiographic lumbar spinal stenosis and clinical symptoms in the general population: the Wakayama Spine Study. Osteoarthr Cartil. 2013;21(6):783–8.
26. Ando M, Tamaki T, Kawakami M, Minamide A, Nakagawa Y, Maio K, Enyo Y, Yoshida M. Electrophysiological diagnosis using sensory nerve action potential for the intraforaminal and extraforaminal L5 nerve root entrapment. Eur Spine J. 2013;22(4):833–9.
27. Iwasaki H, Yoshida M, Yamada H, Hashizume H, Minamide A, Nakagawa Y, Kawai M, Tsutsui S. A new electrophysiological method for the diagnosis of extraforaminal stenosis at L5–S1. Asian Spine J. 2014;8(2):145–9.
28. Eguchi Y, Ohtori S, Yamashita M, Yamauchi K, Suzuki M, Orita S, Kamoda H, Arai G, Ishikawa T, Miyagi M, Ochiai N, Kishida S, Masuda Y, Ochi S, Kikawa T, Takaso M, Aoki Y, Toyone T, Suzuki T, Takahashi K. Clinical applications of diffusion magnetic resonance imaging of the lumbar foraminal nerve root entrapment. Eur Spine J. 2010;19(11):1874–82.

JAPAN JOURNAL OF
NURSING SCIENCE

Japan Journal of Nursing Science (2014) doi:10.1111/jjns.12065

REVIEW ARTICLE

Literature review of pain management for people with chronic pain

Yukari TAKAI,[1] Noriko YAMAMOTO-MITANI,[1] Yoshiki ABE[2] and Mizue SUZUKI[3]

[1]*Department of Adult Nursing/Palliative Care Nursing, Division of Health Sciences and Nursing, Graduate School of Medicine, the University of Tokyo, Tokyo,* [2]*School of Nursing, University of Tsukuba, Tsukuba, Ibaraki and* [3]*Faculty of Nursing, Hamamatsu University School of Medicine, Hamamatsu, Sizuoka, Japan*

Abstract

Aim: Multimodal approaches toward relieving pain, patients' participation, and improving self-efficacy are important for chronic pain management. The aims of this review were to identify possible options of nursing strategies for pain management in individuals with chronic pain and to determine the effectiveness of these strategies for pain relief/pain-related problems; therefore, nurses and researchers could consider and/or adopt multimodal chronic pain management strategies.

Methods: A Systematic Integrated Literature Review was conducted. Published work related to pain management in individuals with chronic pain was identified by searching databases and reviewed.

Results: Among the studies reviewed, we identified 35 studies that focused on pain management strategies. In 10 studies, interventions such as integrated and multidisciplinary pain management programs were associated with significant decreases in pain intensity. However, they reported that the long-term effectiveness of pain relief was not satisfactory. Individuals with chronic pain reported that strategies including pharmacotherapy, physical activity, social support from friends and family, acupuncture, heating, rest, diets, or life-style changes helped them to effectively manage their pain.

Conclusion: We identified possible options of pain management strategies and explored effectiveness of chronic pain interventions. The long-term effects of pain relief interventions and social support for individuals with chronic pain require further investigation.

Key words: chronic pain, pain management, review, self-efficacy, self-management.

INTRODUCTION

Pain is an important health alert for human beings that could inform them of potential health problems. However, pain is sometimes persistent and exceeds the normal healing process, which can lead to unpleasant feelings and negative consequences for their lives. Many people suffer from chronic pain; the prevalence of chronic pain was reported as 45.2% in people living in the Japanese community (Nakamura, Nishiwaki, Ushida, & Toyama, 2014). Furthermore, chronic pain can cause physical disability, depression, a lower quality of life, or financial and employment difficulties (Achterberg *et al.*, 2010; Gillespie & Friedman, 2007; Johannes, Le, Zhou, Johnston, & Dworkin, 2010). Appropriate pain management was extremely important for individuals with chronic pain to maintain their daily activities as much as possible, as individuals incapacitated by chronic pain are prone to inactivity and focus their attention on their pain throughout the day.

Pain management is defined as the intention to modulate patients' pain or their response to pain using

Correspondence: Yukari Takai, Department of Adult Nursing/Palliative Care Nursing, Division of Health Sciences and Nursing, Graduate School of Medicine, the University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan. Email: takaiyukari-tky@umin.ac.jp

Received 24 June 2014; accepted 16 September 2014.

multimodal approaches in a collaborative relationship with the patient, with the aim of self-efficacy (Larsen, 2007). Because of the refractory nature of chronic pain, the goal of pain management may not depend on the level of pain the patient experiences (Richardson, Adams, & Poole, 2006).

Rather, relieving pain as much as possible in individuals with chronic pain is considerably important to motivate them to engage in new or positive behaviors, such as physical activity and exercise (Oliver & Ryan, 2004). Pharmacological therapy for pain relief could be effective, however, side-effects and adverse events of pharmacological therapy for pain were also reported among people undergoing long-term therapy for chronic pain (Finnerup, Sindrup, & Jensen, 2010; Planton & Edlund, 2010). Therefore, a combined strategy with alternative and pharmacological therapies are often needed for individuals with chronic pain.

The patient's participation in pain management also is necessary (Austrian, Kerns, & Reid, 2005); however, multimodal approaches in a collaborative relationship with patients have not been fully explored. Health professionals need to understand patients' perception toward their pain management and provide options to manage pain according to them.

In particular, knowing the effectiveness of chronic pain management strategies and their long-term effects in individuals with chronic pain are important. Nurses should access reviews of chronic pain management, such as self-management programs for musculoskeletal pain (Du *et al.*, 2011; Nuñez, Keller, & Ananian, 2009; Reid *et al.*, 2008) and the nurse's role in pain management (Courtenay & Carey, 2008; Dewar, 2006; Richardson *et al.*, 2006; Shin & Kolanowski, 2010). However, these reviews mainly focus on the nurse's role and self-management of musculoskeletal pain. There are no recent reviews regarding the management of other types of chronic pain, such as neuropathic pain. It is important that nurses understand multimodal strategies available for chronic pain management.

Therefore, the aims of this review are to identify pain management strategies for/by individuals with chronic pain from quantitative and qualitative studies, and to examine the effectiveness of these pain management strategies for pain relief/pain-related problems. A greater understanding of the strategies would help Japanese nurses to develop nursing systems for managing chronic pain and explore research areas that require further investigation.

METHODS

This review was conducted as a Systematic Integrated Literature Review, as described by Im and Chang (2012). This type of review is defined as systematic based on the methods used to retrieve, sort, and analyze the studies; the explicit description of the methods; and the comprehensive inclusion of all available sources of information.

To identify areas relating to chronic pain management strategies and their effectiveness, we selected reports on trials (e.g. randomized clinical trials [RCT], quasi-experimental design trials, and single group studies) and cross-sectional studies that examined pain management strategies. We aimed to identify the areas of strategies/interventions for chronic pain management that nurses could consider using; we also selected reports of qualitative research, through in-depth interviews and descriptive studies, which explored perceptions of effective pain management strategies.

Published work related to pain management for individuals with chronic pain was collected by searching PubMed and the Japan Medical Abstracts Society's web database in August 2013. We searched abstracts and titles of manuscripts written in English or Japanese that were published in the last 8 years (2006–2013) using key words such as pain "management", "chronic pain", and "nursing". In this study, pain resulting from a non-life-threatening cause that persisted for more than 6 months was defined as chronic pain (West, Usher, & Foster, 2011). This search identified 394 reports.

Studies were included if they met the following inclusion criteria: they involved targeted patients with chronic non-malignant pain as a study population; patients were at least 18 years of age; they were written in English or Japanese; they were interventional studies of patients with chronic pain, which could possibly be adopted by Japanese nurses; and they were qualitative or descriptive studies exploring patient preferences and/or evaluations regarding strategies for their chronic pain.

Published work was excluded if it was related to medical strategies for treatment that were not normally performed by nurses in Japan ($n = 2$); related to strategies for malignant cancer pain ($n = 21$); related to neonates and children ($n = 8$); related to acute pain only ($n = 19$); related to strategies involving nursing staff only ($n = 6$); related to symptoms/conditions other than pain ($n = 20$); was not written in English or Japanese ($n = 28$); did not focus on chronic pain management interventions or strategies ($n = 105$); was a scale development study ($n = 6$); was a case report with a small sample size (e.g. one or two cases; $n = 4$); or was a published work review/opinion paper ($n = 131$).

The studies reviewed here examined strategies implemented for individuals with chronic pain or that patients used for their chronic pain and/or perceived as effective pain management. For chronic pain management studies of patients with chronic pain that were conducted using a trial or quasi-experimental design, we reviewed reports that focused on pain management strategies, participants, and settings, and study findings relating to pain intensity, and other variables; these have been reported in Table 1. When included studies used any theoretical framework/interventional approaches, they were also reported in Table 1. In order to identify perceptions of effective pain management strategies in individuals with chronic pain, qualitative, and descriptive studies focusing on patient perceptions regarding chronic pain management strategies were reviewed by focusing on data collection methods, participants, pain types or causes, and findings (Table 2).

RESULTS

Study characteristics

Of the 394 studies reviewed, 35 met the criteria for this study and were selected for further analysis. The studies were conducted in the USA ($n = 10$), Canada ($n = 5$), Taiwan ($n = 4$), Norway ($n = 4$), Australia ($n = 3$), Hong Kong ($n = 2$), China ($n = 1$), Denmark ($n = 1$), Iceland ($n = 1$), New Zealand ($n = 1$), Spain ($n = 1$), Switzerland ($n = 1$), and the UK ($n = 1$).

For the reviewed studies, participants were recruited from outpatient medical centers, clinics, and general practitioners' offices ($n = 16$); the community ($n = 12$); long-term care facilities and nursing homes ($n = 4$); and inpatient facilities and hospitals ($n = 3$). Many studies included subjects who were 18 years old and over ($n = 14$), and nine studies focused on older adults. Eight studies excluded people with a history of mental disorders or cognitive impairment.

Some studies focused on specific conditions, such as pain related to osteoarthritis ($n = 5$), back pain ($n = 4$), fibromyalgia pain ($n = 4$), headache ($n = 1$), chronic angina pain ($n = 1$), chronic deep nipple pain ($n = 1$), pain among people undergoing hemodialysis therapy ($n = 1$), and pain related to rheumatic disease ($n = 1$).

There were several types of studies reported, including RCT ($n = 8$), quasi-experimental ($n = 15$), and qualitative or descriptive studies ($n = 12$).

Intervention for chronic pain management in trials and quasi-experimental designs

Interventional strategies

Fourteen studies used multidisciplinary or multimodal strategies in which subjects adopted self-management strategies for chronic pain; two of these studies included patient intervention and staff education together (Haller *et al.*, 2011; Tse & Ho, 2013). Relaxation and guided imagery ($n = 2$), and music therapy ($n = 1$) were also used. A pain diary was used in three studies, which aimed to facilitate effective communication between healthcare professionals and individuals with chronic widespread pain and to assess patient pain and conditions (Hager & Brockopp, 2007; Kristjánsdóttir *et al.*, 2013; Nes, Eide, Kristjansdottir, & van Dulmen, 2013); two of these studies included web-based or smartphone-based interventions.

Effectiveness of pain relief

Eighteen studies reported the effects of their interventions on pain intensity in individuals with chronic pain. Ten studies reported that their intervention statistically significantly decreased pain intensity or provided pain relief. For example, an integrated pain management program for older residents' pain (Tse & Ho, 2013), Kinesio Taping for low back pain (Castro-Sánchez *et al.*, 2012), a multidisciplinary pain management program (Dysvik, Kvaløy, & Natvig, 2012), a collaborative quality improvement program (Haller *et al.*, 2011), music intervention for people suffering from fibromyalgia pain (Onieva-Zafra, Castro-Sánchez, Matarán-Peñarrocha, & Moreno-Lorenzo, 2013), a small multidisciplinary chronic pain management program (Burnham, Day, & Dudley, 2010), relaxation and guided imagery for people with fibromyalgia pain (Menzies & Kim, 2008), the Calgary Headache Assessment and Management Program (Sauro & Becker, 2008), the Arthritis Self-Help Course and the Chronic Disease Self-Management Program (Goeppinger, Armstrong, Schwartz, Ensley, & Brady, 2007), and an arthritis self-management program (Yip *et al.*, 2007) were reported. The studies that used Kinesio Taping (Castro-Sánchez *et al.*, 2012), music interventions (Onieva-Zafra *et al.*, 2013), and self-management programs (Yip *et al.*, 2007) used RCT. Long-term effects were also reported in two studies. Dysvik *et al.* (2012) reported that the score of bodily pain for the SF-36 improved after implementing a multidisciplinary pain management program for 12 months, but these changes were not significant after Bonferroni correction.

Table 1 Chronic pain management studies for patients with chronic pain by using a trial or quasi-experimental design

Authors, (published year), country	Sample and settings	Pain types/causes	Design	Frameworks/interventional approach	Intervention	Pain intensity scales	Results: pain intensity	Results: other variables
Tse and Ho (2013), Hong Kong	Nursing home residents, IG = 48, CG = 42	NA	Quasi-experimental pretest and post-test control group study	Snoeselen	Integrated pain management program, received instruction in gardening activities and physiotherapy activities for 8 weeks and 8 week physiotherapy program and acupressure and massage	Geriatric Pain Assessment	The residents in the IG reported significantly lower pain scores and used more non-drug strategies for pain relief compared with the control group (week 8)	Happiness, loneliness, life satisfaction, and geriatric depression had significantly improved among the residents in the IG
Barrett *et al.* (2013), USA	Patients diagnosed as having Raynaud's phenomenon of the nipple at a dermatological referral center ($n = 18$)	Chronic deep nipple pain during lactation	Retrospective medical record review	CBT and acceptance and commitment therapy	Treatment and counseling: (i) wear warm clothing; (ii) take hot showers twice daily before breast-feeding; and (iii) avoid caffeine and vasoconstrictive drugs to prevent precipitation of vasospasm	A 25 question follow-up survey (the quality of pain and symptoms experienced)	10 (83%) reported decreased or resolution of pain	All patients reported marked improvement of symptoms and were able to continue breast-feeding
Nes *et al.* (2013), Norway	Patients in the hospital, IG = 48, CG = 37	Chronic widespread pain	RCT	CBT and acceptance and commitment therapy	Three web-based interventions incorporating electronic diaries and situational feedback consisting of one face-to-face session and 4 weeks of web-based communication	VAS	NA	After the follow-up period, the IG reported less catastrophizing compared with the CG. Between-group effect size on catastrophizing was large (Cohen's $d = 0.87$, $P < 0.001$) and remained moderate (0.74, $P = 0.003$) 6 months after discharge from the inpatient program

Kristjánsdóttir *et al.* (2013), Norway	Female patients in the rehabilitation center, IG = 48, CG = 64	Chronic widespread pain	RCT	CBT and acceptance and commitment therapy	Smartphone intervention consisting of one face-to-face session and 4 weeks of written communication via a smartphone	VAS	No effect was found on pain level between intervention and control groups (effect size, −0.05 and −0.04, respectively)	Immediately after the intervention, the IG reported less catastrophizing than the CG, yielding a large effect size (Cohen's d = 0.87, $P < 0.001$) for study completers. At 5 months of follow up, the between-group effects size remained moderate for catastrophizing (0.74, $P = 0.003$), acceptance of pain (0.54, $P = 0.02$), and functioning and symptom levels (0.75, $P = 0.001$)
Onieva-Zafra *et al.* (2013), Spain	Sixty patients from fibromyalgia associations, IG = 30, CG = 30	Fibromyalgia pain	RCT	NA	Music interventions consisted of listening to music once a day for 4 consecutive weeks using two types of CDs	McGill Pain Questionnaire VAS	The participants in IG reported a significant reduction in pain at week 4 compared with the baseline interview, whereas CG participants reported no reduction in their pain at week 4 versus baseline scores. Differences in the IG regarding VAS at baseline and at week 4 also were significant	Mean depression scores from baseline to week 4 improved for the IG

Table 1 *Continued*

Authors, (published year), country	Sample and settings	Pain types/ causes	Design	Frameworks/ interventional approach	Intervention	Pain intensity scales	Results: pain intensity	Results: other variables
Ryan, Packham, Dawes, and Jordan (2012), UK	Fibromyalgia patients at clinics and community rheumatology services, IG = 60, CG = 74	Chronic musculoskeletal pain	A retrospective study	Goal-setting and self-management principle and skills acquisition	Pain clinic attendance	NA	NA	In the 3 years following attendance at the pain clinic, the mean number of hospital appointments fell significantly. The mean reduction seen in hospital clinic attendances in the first year improved in the second and third years
Castro-Sánchez *et al.* (2012), Australia	Adults attended a clinic, n = 60	Chronic non-specific low back pain	RCT	NA	Kinesio Taping	VAS	Experimental group also had a greater decrease in pain than the control group immediately after treatment, which was maintained 4 weeks later	At 1 week, the experimental group had significantly greater improvement in disability, however, these effects were not significant 4 weeks later.
Dysvik *et al.* (2012), Norway	Participants, excluded older adults, were recruited through their general practitioners, n = 104	Chronic non-malignant pain	Follow-up quasi-experimental design and a previous control group	CBT	Pain management program based on CBT consisting of an 8 week basic course and follow up at 6 and 12 months	Brief Pain Inventory (BPI)	Indications of further improvements were seen in bodily pain and maintenance after 12 months, although these changes disappeared after a Bonferroni correction. No important differences were found when the changes in the SF-36 and pain intensity scores from post-test to 12 months were compared between the present studies	Findings suggest that this follow-up program can potentially maintain the positive results of the basic program in terms of reduced pain perception, improved health-related quality of life, and movement towards self-management

Wu *et al.* (2011), Taiwan	Aged 50 years and over recruited in the community health centers, n = 215	OA pain of the knee	Quasi-experimental study	CBT based on Bandura's concept of self-efficacy and behavior change	This program trial was a 4 week arthritis program followed by an 8 week follow-up assessment. There were four 80 min classes held once a week, each with 10–15 participants	NA	NA	At post-intervention, significant differences were found in pain beliefs and pain days. At 8 week follow up, there was a significant improvement in arthritis self-efficacy: pain and other symptoms subscales, pain beliefs and number of unplanned medical consultations
Kristjánsdóttir *et al.* (2011), Norway	Female participants (*n* = 6) diagnosed with CWP or FMS in the rehabilitation center or by GP	Chronic widespread pain	Pre- and post-test study	Mindfulness-based CBT Bandura's concept of self-efficacy	The intervention included daily online entries and individualized written feedback, grounded in a mindfulness-based CBT approach. The participants registered activities, emotions and pain cognitions three times daily using the mobile device	NRS	No differences	Intervention was rated as supportive, meaningful, and user-friendly by the majority of the women. The response rate to the daily registration entries was high and technical problems were few
Haller *et al.* (2011), Switzerland	All adult patients at a teaching hospital, n = 1237 in pre-program, n = 1113 in post-program	NA	Pre- and post-test study	NA	Implementation of a collaborative quality improvement program using multifaceted interventions (staff education, opinion leaders, patient education, audit, and feedback) to improve pain management at hospital level	A question: "Do you think the hospital staff did everything they could to help control your pain?"	For the patients who did not undergo surgery, 70.4% stated "Yes, definitely" (post-program) vs 57.3% (pre-program) of patients reported full pain relief ($P = 0.008$)	Among non-surgical patients, improvements were observed for pain assessment, pain management, and pain relief

Table 1 *Continued*

Authors, (published year), country	Sample and settings	Pain types/ causes	Design	Frameworks/ interventional approach	Intervention	Pain intensity scales	Results: pain intensity	Results: othervariables
Chen and Francis (2010), Australia	People aged between 25 and 65 years recruited through newspapers, n = 19	Chronic pain	RCT	Bernstein and Borkovec's individualized scripts	A 6 week combined abbreviated progressive relaxation technique (APRT) and guided imagery (GI) intervention	The McGill Pain Questionnaire (MPQ)	Not statistically significant	Regarding outcomes for mental health, the results indicated a lack of statistically significant improvements for IG. Results from the quality of life measure indicated that there was a consistent trend of improvement for IG
Burnham *et al.* (2010), Canada	Patients at a clinic Full multidisciplinary management, n = 29 Supervised medication management, n = 53	Chronic spinal pain	Pretest and post-test control group study	NA	Supervised medication management or full multidisciplinary management.	NRS	There was significant reduction in pain intensity in the full multidisciplinary group and medication management group, but not significantly different between groups	
Davis and White (2008), USA	Residents at three independent-living residential settings, n = 17	Chronic musculoskeletal pain related to rheumatic disease	Repeated measures pretest–post-test design	CBT and self-efficacy	This preliminary testing of the Goal Attainment Pain Management Program	NA	Not statistically significant	Results showed that older individuals could successfully participate in setting and attaining individual goals. Exercise and distraction were identified as significantly more helpful
Menzies and Kim (2008), USA	Patients recruited through brochures and newspaper advertisements, n = 10	Fibromyalgia pain	Repeated-measures pretest–post-test design	CBT/mind–body approach	Three 20 min relaxation and GI audiotapes used in a prescribed order for 6 weeks and in any order for weeks 7–10	VAS A short form of the McGill Pain Questionnaire (SF-MPQ)	Significant improvement was observed over time (baseline, 6 weeks and 10 weeks) in the scores of the PPI subscale of the SF-MPQ	

McGillion *et al.* (2008), Canada	Patients living in the community, IG = 57, CG = 60	Chronic angina	RCT	Cognitive–behavioral self-management techniques Bandura's Self-Efficacy Theory	Standardized psych education program given in 2 h sessions weekly, over a 6 week period	SF-36 (bodily pain)	No statistically significant	Significant improvements in IG: physical functioning and general health aspects of generic HRQL. Angina frequency, angina stability, and self-efficacy to manage disease were also significantly improved at 3 months
Sauro and Becker (2008), Canada	Patients are referred to a program by a general practitioner or a specialist, n = 132	Headache	Pre- and post-test study	CBT	The Calgary Headache Assessment and Management Program (CHAMP) 1. Education Session 2. Lifestyle Assessment 3. Self-Management Workshop 4. Nursing Contact and Advice 5. Physician Visit	VAS	Both the number of headache days and the intensity of headaches decreased following Self-Management ($n = 99$). The average intensity of the headaches decreased from baseline to post-workshop	Statistically reliable short-term improvements in HRQL and self-efficacy were found for those who participated in the CHAMP as compared with the control group; specific components of HRQL significantly improved included overall physical functioning and general health (SF-36) and frequency and stability of angina pain symptoms (SAQ)
Sørensen and Frich (2008), Denmark	Adult patients at the Multidisciplinary Pain Center. IG = 52, CG = 49	Chronic non-malignant pain	RCT	NA	The first nurse follow-up visit took place immediately after discharge from the Multidisciplinary Pain Center; further visits were at 4, 8, 12, 16, 20, and 24 months	VAS	Not statistically significant between groups	No statistically significant differences in health status were observed between the two groups after the 2 year intervention period. The costs were no statistically significant between control and intervention groups

Table 1 *Continued*

Authors, (published year), country	Sample and settings	Pain types/ causes	Design	Frameworks/ interventional approach	Intervention	Pain intensity scales	Results: pain intensity	Results: othervariables
Price, McBride, Hyerle, and Kivlahan (2007), USA	Female veterans at a women's clinic, n = 14	Chronic pain	Two group, randomized, repeated-measures design	Mindful Awareness in Body-oriented Therapy	A mind–body approach that incorporates massage, mindfulness, and the emotional processing of psychotherapy	Physical Well-being – The Medical Symptoms Checklist	NA	Study participants adhered to study procedures, and 100% attended at least 7 of 8 sessions; all completed in-person post-treatment assessment
Hager and Brockopp (2007), USA	Patients in a 130 bed not-for-profit facility, n = 21	NA	Pre-experimental design using a one group pretest and post-test method	NA	Chronic pain diary was used for 2 weeks	Pain diary including NRS	Following diary implementation, pain levels, pain-related nursing entries, and use of as-needed medication increased (but not statistically significant)	There was a statistically significant increase in the number of scheduled medications
Goeppinger *et al.* (2007), USA	Participants were recruited from churches, senior centers, n = 416	Any type of arthritis or persistent chronic joint pain	Pretest and post-test control group study	Efficacy-enhancing strategies	Community-based disease self-management interventions using efficacy-enhancing strategies of skill mastery, modeling, symptom reinterpretation, problem solving, and social persuasion	NRS	At 4 months, all participants had statistically significant improvements in pain. Statistically significant differences between the 2 programs at 4 months were seen in pain and disability in both groups	At 4 months, all participants had significant improvements in self-efficacy, stretching and strengthening exercises, aerobic exercises, and general health

Yip *et al*. (2007), China	Patients with OA of the knee were recruited from the specialist or general outpatient clinic and wellness clinic, IG = 67, CG = 53	OA pain	RCT	Bandura's concept of self-efficacy and behavior change	Six 2 h classes held once a week, with 10–15 participants, led by Registered Nurses, focused on teaching participants how to cope with and manage common knee OA consequence, using stretching exercises, walking, and Tai Chi types of movement: fluid, gentle, relaxed and slow in tempo movements	VAS	Reduction of current arthritis pain (effect size, 0.613; $P = 0.0001$)	At 16 weeks, statistically significant improvement; arthritis self-efficacy level, self-management skills, the duration of light exercise practice, reduction of current arthritis pain and in the ability to perform daily activities among the IG but not for the CG
Elliott, Chapman, and Clark (2007), USA	Patients in the primary pain clinic, n = 36	Persistent pain	Prospective, descriptive, quantitative, exploratory design	Behavioral therapy	Patients were evaluated for activity levels, analgesia, side-effects of medication, adverse behaviors, medication use, and follow-through on previously placed consults in the distance-clinic, behavioral therapy implemented as appropriate		NA	Results showed the use of videoconferencing for this group of patients is useable and satisfactory for both patients and staff, that the patients save time and money

CHAMP, The Calgary Headache Assessment and Management Program; CBT, cognitive–behavior therapy; CG, control group; CWP, chronic widespread pain; FMS, fibromyalgia syndrome; HRQL, health-related quality of life; IG, intervention group; NA, not applicable/available; NRS, Numeric Rating Scale; OA, osteoarthritis; PPI, present pain intensity; RCT, randomized controlled trials; VAS, visual analog scale.

Table 2 Perception on effective pain management among people with chronic pain from qualitative or descriptive research

Authors (published year), country	Data collection methods	Participants	Pain type or causes	Findings
Kawi (2014), USA	Interview	Patients at two pain centers, n = 110	Chronic Low back pain	Perceptions of self-management: taking medications, maintaining physical activity, making wise decisions and changes in lifestyle, using heat and cold applications, rest and relaxation, using other physical and alternative modalities
Stinson *et al.* (2013), Canada	Semistructured group interview	Young adults aged 18–29 years from two adult tertiary care multidisciplinary chronic pain clinics, n = 17	Chronic pain	Psychological, physical, and pharmacological approaches and development of support systems, particularly highlighted physical and pharmacological strategies and support systems
Bourbonnais and Tousignant (2012), Canada	Semistructured interview	Dialysis patients from a large tertiary care hospital, n = 25	Not specific	Analgesics, exercise, keeping a positive attitude
West *et al.* (2012), Australia	In-depth interview	As part of the larger study, n = 10	Chronic pain	The meaning of resilience to persons with chronic pain; e.g. recognizing individual strength, looking for the positives in life, not giving in to the pain, developing tolerance to pain, understanding how to manage your pain
Kengen Traska *et al.* (2012), USA	Group interview	Women with fibromyalgia, n = 8	Fibromyalgia	Main strategies included: pacing/planning, distraction techniques, coping with touch sensitivity, putting on the mask and medications. Social support from others with fibromyalgia and from family members was reported to be very important
Tsai *et al.* (2010), Taiwan†	Questionnaire	Elderly persons from outpatient clinics, n = 1054	Not specific	The three most highly effective self-care strategies for managing pain, excluding having an injection and operation, were acupuncture, changing diet, and meditation
Crowe *et al.* (2010), New Zealand	Semistructured interview	Participants were recruited via two different avenues, n = 64	Chronic low back pain	The most common strategies used by participants to manage their chronic low back pain were medication, exercise, and application of heat. The nominated healthcare professionals were predominantly physiotherapists and GPs. Most participants recognized exercise as effective, were generally resistant to taking medication regularly, and found that application of heat relieved the pain

Gudmannsdottir and Halldorsdottir (2009), Iceland	Interview	Residents in the three nursing homes, n = 12	Chronic pain	Sources of strength and joy in the lives and being able to keep their health considerably good; visits or phone calls from loved ones and a token of being cared for, taking part in physical exercises alone or in a group, going out in the sun and staying there
Chiou *et al*. (2009), Taiwan†	Interview and questionnaire	Older persons diagnosed with either rheumatoid arthritis or osteoarthritis from two medical centers, n = 151	OA	The most effective methods included taking prescribed medications, using assistive devices and self-talking. (the three least effective techniques were ignoring the pain, alternative medical therapies, and over-the-counter medications)
Meghani and Cho (2009), USA†	Telephone survey	Nationwide telephone survey, n = 902	Any type of pain	There was an inverse relationship between age and perception that complementary and alternative medicine (CAM) was effective for pain. Individuals with higher average daily pain were also less likely to perceive CAM as effective
Tsai *et al*. (2008), Taiwan†	Questionnaire	Elderly participants were recruited by convenience sampling from three outpatient clinics at a medical center, n = 205	OA	Taking a rest, do not move, lying down on a bed, going to sleep, massaging the pain site, using a heating pad. The most effective strategies were stopping one's activity (e.g. take a rest, go to sleep, lie down) and massage (e.g. use a heating pad)
Chung and Wong (2007), Hong Kong†	Questionnaire	Subjects were recruited by random digit dialing sampling, n = 1,853	Not specific	Pain relief methods: seeking medical advice was the most common relief measure taken to alleviate pain. Both traditional Chinese medicine and alternative methods were popular

†Cross-sectional study. OA, osteoarthritis.

Goeppinger *et al.* (2007) reported that statistically significant differences in pain intensity were not maintained at 12 months.

The chronic pain management strategies mentioned above were adapted on the basis of several theoretical frameworks or approaches, including cognitive–behavioral therapy (CBT), mind–body (Menzies & Kim, 2008) or mindful awareness approaches (Kristjánsdóttir *et al.*, 2011), acceptance and commitment therapy (Barrett, Heller, Stone, & Murase, 2013; Kristjánsdóttir *et al.*, 2013; Nes *et al.*, 2013), concept of self-efficacy and behavior change (Davis & White, 2008; McGillion *et al.*, 2008; Wu, Kao, Wu, Tsai, & Chang, 2011; Yip *et al.*, 2007), and Roger's theory of science of unitary human beings (Onieva-Zafra *et al.*, 2013).

Perspectives of pain management strategies among patient with chronic pain from qualitative and descriptive research

Twelve studies reported the perceptions of effective pain management strategies from individuals with a chronic condition of pain. For example, people perceived that pharmacotherapy, physical activity, support from friends and family members, acupuncture, heating, rest, diets, and lifestyle changes were effective for chronic pain management (Bourbonnais & Tousignant, 2012; Chiou, Lin, & Huang, 2009; Chung & Wong, 2007; Crowe, Whitehead, Jo Gagan, Baxter, & Panckhurst, 2010; Gudmannsdottir & Halldorsdottir, 2009; Kawi, 2014; Kengen Traska, Rutledge, Mouttapa, Weiss, & Aquino, 2012; Meghani & Cho, 2009; Stinson *et al.*, 2013; Tsai, Chu, Lai, & Chen, 2008; Tsai, Liu, & Chung, 2010). An interpretive qualitative study reported that people with chronic pain explained that "recognizing individual strength", "accepting pain", "looking for the positive aspects of life", and "learning to accept help" were frequently used coping strategies for living with chronic pain (West, Stewart, Foster, & Usher, 2012). Kawi (2014) reported that medication and maintaining physical activity were predominant strategies for self-management. A content analysis of experience among women with fibromyalgia revealed that the primary strategies for coping with pain were "pacing or planning", "distraction techniques", "coping with touch sensitivity", "putting on a mask", and "medications" (Kengen Traska *et al.*, 2012).

Individuals with chronic pain reported that they sought social supports for their pain management. For example, participants stated their family members and friends offered support and made them feel stronger, although they were facing adversity (West *et al.*, 2012). Another study reported that individuals with fibromyalgia found that talking to a friend and participating in support groups for fibromyalgia were useful for pain management (Kengen Traska *et al.*, 2012).

DISCUSSION

Herein, we reviewed strategies for pain management in individuals with chronic pain and examined the effectiveness of these strategies; therefore, nurses and researchers could consider and adopt these as chronic pain management strategies. Several studies used multidisciplinary and multimodal interventions as pain management strategies for people with chronic pain and reported effective pain relief. For example, education for individuals with chronic pain was used in conjunction with pain relief strategies such as pharmacological therapy, relaxation, and physical activity that were often provided by a multidisciplinary team. Because chronic pain is intractable, persistent, and has physical and psychosocial effects, the multimodal and interprofessional teamwork approaches were exceedingly important (AGS Panel on Persistent Pain in Older Persons, 2002). The long-term effectiveness of pain relief was not satisfactory and should be explored further in research.

According to qualitative studies, individuals with chronic pain perceived that social supports were effective for their pain management. For example, talking with their family or friends and participation in patient groups were effective in managing pain (Kengen Traska *et al.*, 2012; West *et al.*, 2012). However, the effectiveness of social supports was not examined in trials. The social resources that remain close to individuals with chronic pain may work over long periods with minimal costs. In contrast, Dysvik, Natvig, Eikeland, and Lindstrøm (2005) found that the most predominant stressors among people with chronic pain were family life and social activities. Social interactions with family members or friends for individuals experiencing pain, as well as the impact of these interactions, are complex. However, supporting families to help them cope with pain and to protect against future crises could be a worthwhile approach for nurses (Lewandowski, Morris, Draucker, & Risko, 2007; West *et al.*, 2011); this area should be examined further.

Although a high prevalence of pain among people living in nursing homes (Takai, Yamamoto-Mitani, Okamoto, Koyama, & Honda, 2010) was reported, we found little research that focused on individuals living in nursing homes or those with dementia or mental illness. Eight studies excluded people with cognitive impairment or diagnoses of mental disease. Pain often has psychological consequences, such as depression, anxiety, or behavioral and psychological symptoms of dementia (Husebo, Ballard, & Aarsland, 2011; Smalbrugge, Jongenelis, Pot, Beekman, & Eefsting, 2007). A systematic review described only three studies that supported the notion that pain management reduced agitation (Husebo *et al*., 2011). However, intervention for vulnerable individuals should be explored; further studies are important.

Limitations

There are some limitations to this review. This review examined recent studies; therefore, long-term trends in pain management were not identified. Furthermore, studies in this review were identified by searching databases. Thus, it is possible that not all studies related to chronic pain management were identified.

Implications in daily practice

Pain management provided through multidisciplinary and multimodal approaches that used CBT concepts and self-efficacy to manage pain were effective for individuals with chronic pain. Because many people suffer from pain in our Japanese society, these strategies should be provided by general healthcare specialists, as well as those in pain clinics, and target individuals in the community through outpatient facilities, community centers, and long-term care facilities. Individuals with chronic pain also stated that they accepted pain and were committed to valued behaviors that included pacing themselves and optimism, which are important concepts in CBT. However, among nurses, a lack of education or training in CBT principles have been identified (Richardson *et al.*, 2006). Continuous education for nurses and the development of systematic approaches to pain management should be explored further.

CONCLUSIONS

This review aimed to identify strategies for pain management in individuals with chronic pain and to explore the effectiveness of pain relief. Multidisciplinary and multimodal approaches were often used in chronic pain interventions. Chronic pain management strategies were adapted on the basis of several theoretical frameworks, such as CBT, mind–body approaches, and concepts of self-efficacy. Individuals with chronic pain perceived that social supports were effective for their pain management. Further studies regarding the intervention of individuals with cognitive impairment or mental illness were facilitated.

ACKNOWLEDGMENT

This research was funded by a Grant-in-Aid for Scientific Research (B) from the Ministry of Education, Culture, Sports, Science and Technology in Japan.

CONFLICT OF INTEREST

None of the authors have any known conflicts of interest.

AUTHOR CONTRIBUTION

Conception and design of the study: Y. T., N. Y. M., Y. A., and S. M.; acquisition of data: Y. T., N. Y. M., Y. A., and S. M.; analysis and interpretation of data: Y. T., N. Y. M., Y. A., and S. M.; drafting the article: Y. T. and N. Y. M.; critical revision for important intellectual content: Y. T.; final approval of the manuscript: Y. T., N. Y. M., Y. A., and S. M.

REFERENCES

Achterberg, W. P., Gambassi, G., Finne-Soveri, H., Liperoti, R., Noro, A., Frijters, D. H. *et al.* (2010). Pain in European Long-Term Care Facilities: Cross-national study in Finland, Italy and the Netherlands. *Pain*, *148*, 70–74.

AGS Panel on Persistent Pain in Older Persons. (2002). The management of persistent pain in older persons. *Journal of American Geriatrics Society*, *50*, 205–224.

Austrian, J. S., Kerns, R. D. & Reid, M. C. (2005). Perceived barriers to trying self-management approaches for chronic pain in older persons. *Journal of the American Geriatrics Society*, *53*, 856–861.

Barrett, M. E., Heller, M. M., Stone, H. F. & Murase, J. E. (2013). Raynaud phenomenon of the Nipple in breastfeeding mothers: An underdiagnosed cause of nipple pain. *JAMA Dermatology*, *149*, 300–306.

Bourbonnais, F. F. & Tousignant, K. F. (2012). The pain experience of patients on maintenance hemodialysis. *Nephrology Nursing Journal*, *39*, 13–19.

Burnham, R., Day, J. & Dudley, W. (2010). Multidisciplinary chronic pain management in a rural Canadian setting. *Canadian Journal of Rural Medicine*, *15*, 7–13.

Castro-Sánchez, A. M., Lara-Palomo, I. C., Matarán-Peñarrocha, G. A., Fernández-Sánchez, M., Sánchez-Labraca, N. & Arroyo-Morales, M. (2012). Kinesio taping reduces disability and pain slightly in chronic non-specific low back pain: A randomised trial. *Journal of Physiotherapy*, *58*, 89–95.

Chen, Y. L. & Francis, A. J. (2010). Relaxation and imagery for chronic, nonmalignant pain: Effects on pain symptoms, quality of life, and mental health. *Pain Management Nursing*, *11*, 159–168.

Chiou, A. F., Lin, H. Y. & Huang, H. Y. (2009). Disability and pain management methods of taiwanese arthritic older patients. *Journal of Clinical Nursing*, *18*, 2206–2216.

Chung, J. W. & Wong, T. K. (2007). Prevalence of pain in a community population. *Pain Medicine*, *8*, 235–242.

Courtenay, M. & Carey, N. (2008). The Impact and effectiveness of Nurse-Led Care in the management of acute and chronic pain: A review of the literature. *Journal of Clinical Nursing*, *17*, 2001–2013.

Crowe, M., Whitehead, L., Jo Gagan, M., Baxter, D. & Panckhurst, A. (2010). Self-management and chronic low back pain: A qualitative study. *Journal of Advanced Nursing*, *66*, 1478–1486.

Davis, G. C. & White, T. L. (2008). A goal attainment pain management program for older adults with arthritis. *Pain Management Nursing*, *9*, 171–179.

Dewar, A. (2006). Assessment and management of chronic pain in the older person living in the community. *Australian Journal of Advanced Nursing*, *24*, 33–38.

Du, S., Yuan, C., Xiao, X., Chu, J., Qiu, Y. & Qian, H. (2011). Self-management programs for chronic musculoskeletal pain conditions: A systematic review and meta-analysis. *Patient Education and Counseling*, *85*, e299–e310.

Dysvik, E., Kvaløy, J. T. & Natvig, G. K. (2012). The Effectiveness of an Improved Multidisciplinary Pain Management Programme: A 6- and 12-Month Follow-up Study. *Journal of Advanced Nursing*, *68*, 1061–1072.

Dysvik, E., Natvig, G. K., Eikeland, O. J. & Lindstrøm, T. C. (2005). Coping with chronic pain. *International Journal of Nursing Studies*, *42*, 297–305.

Elliott, J., Chapman, J. & Clark, D. J. (2007). Videoconferencing for a Veteran's Pain Management Follow-up Clinic. *Pain Management Nursing*, *8*, 35–46.

Finnerup, N. B., Sindrup, S. H. & Jensen, T. S. (2010). The Evidence for Pharmacological Treatment of Neuropathic Pain. *Pain*, *150*, 573–581.

Gillespie, S. M. & Friedman, S. M. (2007). Fear of Falling in New Long-Term Care Enrollees. *Journal of the American Medical Directors Association*, *8*, 307–313.

Goeppinger, J., Armstrong, B., Schwartz, T., Ensley, D. & Brady, T. J. (2007). Self-Management Education for Persons with Arthritis: Managing Comorbidity and Eliminating Health Disparities. *Arthritis and Rheumatism*, *57*, 1081–1088.

Gudmannsdottir, G. D. & Halldorsdottir, S. (2009). Primacy of Existential Pain and Suffering in Residents in Chronic Pain in Nursing Homes: A Phenomenological Study. *Scandinavian Journal of Caring Sciences*, *23*, 317–327.

Hager, K. K. & Brockopp, D. (2007). Pilot Project: The Chronic Pain Diary–Assessing Chronic Pain in the Nursing Home Population. *Journal of Gerontological Nursing*, *33*, 14–19.

Haller, G., Agoritsas, T., Luthy, C., Piguet, V., Griesser, A. C. & Perneger, T. (2011). Collaborative Quality Improvement to Manage Pain in Acute Care Hospitals. *Pain Medicine*, *12*, 138–147.

Husebo, B. S., Ballard, C. & Aarsland, D. (2011). Pain Treatment of Agitation in Patients with Dementia: A Systematic Review. *International Journal of Geriatric Psychiatry*, *26*, 1012–1018.

Im, E. O. & Chang, S. J. (2012). A Systematic Integrated Literature Review of Systematic Integrated Literature Reviews in Nursing. *The Journal of Nursing Education*, *51*, 632–640.

Johannes, C. B., Le, T. K., Zhou, X., Johnston, J. A. & Dworkin, R. H. (2010). The Prevalence of Chronic Pain in United States Adults: Results of an Internet-Based Survey. *The Journal of Pain*, *11*, 1230–1239.

Kawi, J. (2014). Chronic Low Back Pain Patients' Perceptions on Self-Management, Self-Management Support, and Functional Ability. *Pain Management Nursing*, *15*, 258–264.

Kengen Traska, T., Rutledge, D. N., Mouttapa, M., Weiss, J. & Aquino, J. (2012). Strategies Used for Managing Symptoms by Women with Fibromyalgia. *Journal of Clinical Nursing*, *21*, 626–635.

Kristjánsdóttir, O. B., Fors, E. A., Eide, E., Finset, A., Stensrud, T. L., van Dulmen, S. *et al.* (2013). A Smartphone-Based Intervention with Diaries and Therapist-Feedback to Reduce Catastrophizing and Increase Functioning in Women with Chronic Widespread Pain: Randomized Controlled Trial. *Journal of Medical Internet Research*, *15*, e5.

Kristjánsdóttir, Ó. B., Fors, E. A., Eide, E., Finset, A., van Dulmen, S., Wigers, S. H. *et al.* (2011). Written Online Situational Feedback Via Mobile Phone to Support Self-Management of Chronic Widespread Pain: A Usability Study of a Web-Based Intervention. *BMC Musculoskeletal Disorders*, *12*, 51.

Larsen, D. (2007). *Pain Management in Nursing: What Does It Mean?* [Cited 18 Mar 2014.] Available from URL: http://www.gb42.com/ynot_what_does_it_mean.html

Lewandowski, W., Morris, R., Draucker, C. B. & Risko, J. (2007). Chronic Pain and the Family: Theory-Driven Treatment Approaches. *Issues in Mental Health Nursing*, *28*, 1019–1044.

McGillion, M. H., Watt-Watson, J., Stevens, B., Lefort, S. M., Coyte, P. & Graham, A. (2008). Randomized Controlled Trial of a Psychoeducation Program for the Self-Management of Chronic Cardiac Pain. *Journal of Pain and Symptom Management*, *36*, 126–140.

Meghani, S. H. & Cho, E. (2009). Self-Reported Pain and Utilization of Pain Treatment between Minorities and

Nonminorities in the United States. *Public Health Nursing*, *26*, 307–316.

Menzies, V. & Kim, S. (2008). Relaxation and Guided Imagery in Hispanic Persons Diagnosed with Fibromyalgia: A Pilot Study. *Family and Community Health*, *31*, 204–212.

Nakamura, M., Nishiwaki, Y., Ushida, T. & Toyama, Y. (2014). Prevalence and Characteristics of Chronic Musculoskeletal Pain in Japan: A Second Survey of People with or without Chronic Pain. *Journal of Orthopaedic Science*, *19*, 339–350.

Nes, A. A., Eide, H., Kristjansdottir, O. B. & van Dulmen, S. (2013). Web-Based, Self-Management Enhancing Interventions with E-Diaries and Personalized Feedback for Persons with Chronic Illness: A Tale of Three Studies. *Patient Education and Counseling*, *93*, 451–458.

Nuñez, D. E., Keller, C. & Ananian, C. D. (2009). A Review of the Efficacy of the Self-Management Model on Health Outcomes in Community-Residing Older Adults with Arthritis. *Worldviews on Evidence-Based Nursing*, *6*, 130–148.

Oliver, S. & Ryan, S. (2004). Effective Pain Management for Patients with Arthritis. *Nursing Standard*, *18*, 43–52; quiz 54, 56.

Onieva-Zafra, M. D., Castro-Sánchez, A. M., Matarán-Peñarrocha, G. A. & Moreno-Lorenzo, C. (2013). Effect of Music as Nursing Intervention for People Diagnosed with Fibromyalgia. *Pain Management Nursing*, *14*, e39–e46.

Planton, J. & Edlund, B. J. (2010). Regulatory Components for Treating Persistent Pain in Long-Term Care. *Journal of Gerontological Nursing*, *36*, 49–56.

Price, C. J., McBride, B., Hyerle, L. & Kivlahan, D. R. (2007). Mindful Awareness in Body-Oriented Therapy for Female Veterans with Post-Traumatic Stress Disorder Taking Prescription Analgesics for Chronic Pain: A Feasibility Study. *Alternative Therapies in Health and Medicine*, *13*, 32–40.

Reid, M. C., Papaleontiou, M., Ong, A., Breckman, R., Wethington, E. & Pillemer, K. (2008). Self-Management Strategies to Reduce Pain and Improve Function among Older Adults in Community Settings: A Review of the Evidence. *Pain Medicine*, *9*, 409–424.

Richardson, C., Adams, N. & Poole, H. (2006). Psychological Approaches for the Nursing Management of Chronic Pain: Part 2. *Journal of Clinical Nursing*, *15*, 1196–1202.

Ryan, S., Packham, J. C., Dawes, T. P. & Jordan, K. P. (2012). The Impact of a Nurse-Led Chronic Musculoskeletal Pain Clinic on Healthcare Utilization. *Musculoskeletal Care*, *10*, 196–201.

Sauro, K. M. & Becker, W. J. (2008). Multidisciplinary Treatment for Headache in the Canadian Healthcare Setting. *Canadian Journal of Neurological Sciences*, *35*, 46–56.

Shin, S. Y. & Kolanowski, A. M. (2010). Best Evidence of Psychosocially Focused Nonpharmacologic Therapies for Symptom Management in Older Adults with Osteoarthritis. *Pain Management Nursing*, *11*, 234–244.

Smalbrugge, M., Jongenelis, L. K., Pot, A. M., Beekman, A. T. & Eefsting, J. A. (2007). Pain among Nursing Home Patients in the Netherlands: Prevalence, Course, Clinical Correlates, Recognition and Analgesic Treatment–an Observational Cohort Study. *BMC Geriatrics*, *7*, 3.

Sørensen, J. & Frich, L. (2008). Home Visits by Specially Trained Nurses after Discharge from Multi-Disciplinary Pain Care: A Cost Consequence Analysis Based on a Randomised Controlled Trial. *European Journal of Pain*, *12*, 164–171.

Stinson, J., White, M., Isaac, L., Campbell, F., Brown, S., Ruskin, D. *et al.* (2013). Understanding the Information and Service Needs of Young Adults with Chronic Pain: Perspectives of Young Adults and Their Providers. *The Clinical Journal of Pain*, *29*, 600–612.

Takai, Y., Yamamoto-Mitani, N., Okamoto, Y., Koyama, K. & Honda, A. (2010). Literature Review of Pain Prevalence among Older Residents of Nursing Homes. *Pain Management Nursing*, *11*, 209–223.

Tsai, Y. F., Chu, T. L., Lai, Y. H. & Chen, W. J. (2008). Pain Experiences, Control Beliefs and Coping Strategies in Chinese Elders with Osteoarthritis. *Journal of Clinical Nursing*, *17*, 2596–2603.

Tsai, Y. F., Liu, L. L. & Chung, S. C. (2010). Pain Prevalence, Experiences, and Self-Care Management Strategies among the Community-Dwelling Elderly in Taiwan. *Journal of Pain and Symptom Management*, *40*, 575–581.

Tse, M. M. & Ho, S. S. (2013). Pain Management for Older Persons Living in Nursing Homes: A Pilot Study. *Pain Management Nursing*, *14*, e10–e21.

West, C., Stewart, L., Foster, K. & Usher, K. (2012). The Meaning of Resilience to Persons Living with Chronic Pain: An Interpretive Qualitative Inquiry. *Journal of Clinical Nursing*, *21*, 1284–1292.

West, C., Usher, K. & Foster, K. (2011). Family Resilience: Towards a New Model of Chronic Pain Management. *Collegian*, *18*, 3–10.

Wu, S. F., Kao, M. J., Wu, M. P., Tsai, M. W. & Chang, W. W. (2011). Effects of an Osteoarthritis Self-Management Programme. *Journal of Advanced Nursing*, *67*, 1491–1501.

Yip, Y. B., Sit, J. W., Fung, K. K., Wong, D. Y., Chong, S. Y., Chung, L. H. *et al.* (2007). Effects of a Self-Management Arthritis Programme with an Added Exercise Component for Osteoarthritic Knee: Randomized Controlled Trial. *Journal of Advanced Nursing*, *59*, 20–28.

Original Article

Differences between Nurses' and Care Workers' Estimations of Pain Prevalence among Older Residents

■■■ ***Yukari Takai, DNSc, RN,*** [*]
Noriko Yamamoto-Mitani, PhD, RN, [*] ***Saori Kawakami, RN,*** [†]
Yoshiki Abe, MHS, RN, [‡] ***Manami Kamiyama, MHS, RN,*** [§]
and Shigeru Saito, PhD, MD [†]

■ Abstract:

A high prevalence of pain and difficulties with pain assessment has been widely reported among residents of long-term-care facilities. We explored nurses' and care workers' estimations of residents' pain (both general and chronic) and the number of residents with unknown pain status. We also examined the relationship between the prevalence of pain and assessment strategies undertaken by nurses and care workers. A cross-sectional design was used. Nurses and care workers across 750 long-term care facilities in four Japanese prefectures were asked to participate. Questionnaires were administered to one nurse and care worker at each facility. The questionnaires assessed the estimated numbers of residents who had pain in general, chronic pain, or unknown pain status on the day of data collection, and pain assessment strategies use by the health care professionals. In all, 263 (17.5%) questionnaires were returned from 147 nurses (55.9%) and 116 care workers (44.1%). The nurses' and care workers' median estimations of pain and chronic pain prevalence among residents were 11.6 and 9.4 and 29.4 and 15.5, respectively ($p < .001$). Estimations of pain prevalence were significantly higher among nurses who had observed signs of pain among residents in the previous month ($p = .04$) and who applied a multidisciplinary approach to pain assessment and management ($p = .007$) than among nurses who did not do either. Nurses and care workers had relatively low estimations of the prevalence of pain among their residents. Staff should undertake appropriate and sufficient pain assessments in order to improve their understanding of residents' pain.

*From the *Department of Adult Nursing/Palliative Care Nursing, Graduate School of Medicine, the University of Tokyo, Tokyo; †Faculty of Medicine, Gunma University Hospital, Maebashi-shi, Japan; ‡School of Nursing, the University of Tsukuba, Tsukuba-shi, Japan; §Graduate School of Health Sciences, Gunma University Hospital, Maebashi-shi, Japan.*

Address correspondence to Yukari Takai, DNSc, RN, Department of Adult Nursing/Palliative Care Nursing, University of Tokyo, Graduate School of Medicine, 7-3-1 Hongo, Bunkyo-Ku, Tokyo, 113-0033 Japan. E-mail: takaiyukari-tky@umin.ac.jp

Received December 18, 2013; Revised March 9, 2014; Accepted March 17, 2014.

This research was funded by a Grant-in-Aid for Scientific Research (23593428) from the Ministry of Education, Culture, Sports, Science and Technology in Japan. The authors state they have no known conflicts of interest.

1524-9042/$36.00

http://dx.doi.org/10.1016/j.pmn.2014.03.005

INTRODUCTION

Pain is defined as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage" (International Association for the Study of Pain, 2011). Pain is primarily conceptualized as a subjective experience. Therefore, obtaining self-reports regarding pain is an important way of facilitating information sharing regarding health problems between health care professionals and individuals suffering from pain.

Older people often have problems with pain. They are more likely to suffer from pain due to chronic illness and age-related changes, such as osteoarthritis, postherpetic neuralgia, trigeminal neuralgia, and central pain after stroke (AGS Panel on Persistent Pain in Older Persons, 2002). These conditions often cause considerable pain among older residents of aged care facilities. Previous studies have demonstrated that 50% to 70% of nursing home residents report being in pain (Boerlage, van Dijk, Stronks, de Wit, & van der Rijt, 2008; Cadogan et al., 2008; Smalbrugge, Jongenelis, Pot, Beekman, & Eefsting, 2007). Other studies have reported that approximately 50% of residents have suffered from chronic pain lasting for more than 3 months (Leong & Nuo, 2007; Won et al., 2004). Pain often causes negative effects for older residents, such as depression, reduced physical ability, and poor sleep quality (Anzai, Shiba, & Haga, 2012; Boerlage et al., 2008; Zanocchi et al., 2007). Therefore, health care professionals must be able to detect problems related to pain and manage them appropriately.

Some issues related to pain among residents at aged care facilities have been raised. Older residents are sometimes reluctant to report their pain to health care staff as a result of stoicism (Hadjistavropoulos, Fitzgerald, & Marchildon, 2010). Japanese older residents have noted that they did not always report their pain to staff; they also believed the pain to be a part of the aging process (Takai, Yamamoto-Mitani, & Ko, 2013). Furthermore, older residents often are unable to report their pain to staff due to physical disability or cognitive impairment (AGS Panel on Persistent Pain in Older Persons, 2002; Takai et al., 2010). In Japan, more than 90% of residents in aged care facilities have some form of cognitive impairment (Ministry of Health Labour and Welfare, 2009). In such circumstances, it is important that health care staff have the necessary skills to appropriately identify and assess pain among their residents.

Residential aged care facilities in Japan play an important role in providing rehabilitation and extended-care services to older adults who have been discharged from the hospital under a long-term care insurance system. The system was established for the systematic provision of health care services that allow these individuals to stay in their homes for as long as possible. At these facilities, a high prevalence of pain has been reported among older residents (Takai et al., 2013), and pain could lead to negative consequences for their rehabilitation. Therefore, staff there must be able to identify and manage pain and its associated problems among residents, which would then facilitate the rehabilitation of these patients.

The importance of pain assessment performed by staff for residents at aged care facilities and the difficulties nurses and care workers encounter in assessing residents' pain have frequently been documented in previous studies (e.g., Takai & Uchida, 2009). Nurses' negative beliefs about the use of pain assessment tools (Young, Horton, & Davidhizar, 2006), lack of recognition of pain, and insufficient education and training (McAuliffe, Nay, O'Donnell, & Fetherstonhaugh, 2009), as well as the importance of observing pain behaviors among residents (Mentes, Teer, & Cadogan, 2004) have been reported. Another Japanese study reported that, compared with care workers, nurses tend to misunderstand the behaviors and perceptions of pain among aged care residents. For example, nurses tend to believe older residents have no pain when they do not complain of it (Takai & Uchida, 2009). This may be due to the fact that there are fewer nurses than care workers at aged care facilities, and nurses are more likely to deal with medical procedures in Japan. Care workers handle the day-to-day care of residents, and thus are more likely encounter residents' pain. Furthermore, only 4.3% of Japanese aged care facilities provide in-service education for staff on pain management (Takai, Yamamoto-Mitani, Fukahori, Kobayashi, & Chiba, 2013). Both groups of health professionals have responsibilities in the appropriate assessment and management of residents' pain. However, studies exploring the number of residents with pain identified by care workers and nurses working at these facilities, or how such identification is associated with assessment strategies employed by health care personnel to ascertain residents' pain status have been few. To better understand how nurses and care workers identify pain in their residents, it is important to detect problems in the assessment strategies of pain in aged care.

Aims

The purpose of this study was to explore estimations by nurses and care workers of the prevalence of pain in general, chronic pain, and the number of residents whose pain status is unknown among residents of Japanese long-term care facilities. A second purpose was to examine the relationship between estimated pain prevalence and the pain assessment strategies used by both nurses and care workers.

MATERIALS AND METHODS

Design, Settings, and Participants

A cross-sectional design was employed. The study sample consisted of nurses and care workers across all long-term aged care facilities in four Japanese prefectures in the Kanto region (N = 750, including two types of facilities, denoted in Japanese as *kaigorojinhokenshisetsu* [n = 593] and *kaigoryoyogata-iryoshisetsu* [n = 157]). Prefectures that were affected by the Great East Japan Earthquake in 2011 were excluded from this study.

Questionnaires with accompanying letters requesting participation in the study were sent to the facilities' nursing managers or administrators. If they agreed to participate, they were asked to choose a residential ward and distribute the questionnaires to a full-time nurse and a full-time care worker (i.e., two employees from each facility were included in the sample).

Data Collection Items

The questionnaire consisted of four parts: 1) the characteristics of the participants, and their wards and facilities; 2) the number of residents in each selected ward who suffered from pain in general, chronic pain, and whose pain status was unknown; 3) perceptions of nurses and care workers regarding pain and pain care; and 4) implementation of pain assessments for residents during the previous month.

First, we explored participants' backgrounds by recording their types of licenses, age, sex, and years of experience as a nurse or care worker. We also evaluated the characteristics of the wards in which they worked, recording ward type, number of residents, number of residents receiving respite care, and number of full- and part-time nurses. Finally, we asked about the characteristics of the participants' facilities, including the age of the facility (in years), the availability of policies regarding pain management, and any in-service education on pain within the past year.

Second, participants estimated the number of residents in their ward who suffered from pain in general, the number who suffered from chronic pain, and the number whose pain status was unknown. The questions were as follows: "At your ward, how many residents complain of pain or may be suffering from pain?" "At your ward, how many residents complain of chronic pain or may be suffering from chronic pain?" and "At your ward, how many residents do you not know the pain status of?" The definition of chronic pain in this study, for example, pain lasting for longer than 1 month, was based on previous studies in Japan (Akamine & Masaki, 2002; Kasai & Tajita, 2001). This was because the average length of stay among aged care facility residents was 98.8 days (Welfare and Medical Service Agency, 2011), we decided that a period of more than 1 month would be appropriate for determining chronic pain in residents among staff there.

Third, we assessed participants' perceptions of pain and pain care. We devised the following items via literature reviews of studies related to pain management in nursing homes (Kaasalainen, 2007; Takai & Uchida, 2009): "Older adults feel less pain than do younger people"; "I do not have enough time to provide care for residents in pain"; "I am satisfied with the pain care strategies that are provided to residents in my facility"; "I think that residents at my ward need chronic pain management strategies"; "I have enough knowledge and skills to assess and manage residents' pain"; and "I have doctors, nurses, or other health professionals whom I could ask about pain management strategies for residents when necessary." The participants were asked to what extent they agreed with each statement by choosing responses from a Likert scale ranging from 1 (*strongly disagree*) to 4 (*strongly agree*).

Finally, we asked participants to provide information on the implementation of pain assessment strategies for residents during the past month, using the assessment portion of a set of guidelines on recommendations for pain and chronic pain management at residential aged care facilities. This set of guidelines was developed by the authors of this study by integrating the contents of 16 guidelines on pain management (e.g., AGS Panel on Persistent Pain in Older Persons, 2002; British Pain Society and British Geriatrics Society, 2007; Hadjistavropoulos et al., 2007). In these guidelines, 42 strategies—including 19 assessment strategies and 23 interventional strategies selected by consensus among pain medicine and aged care experts—were recommended for nurses and care workers. In this study, only the 19 assessment strategies were covered. We asked whether pain assessment strategies for residents were implemented within the past month (answer options were "yes" or "no").

Data Collection Procedure

Questionnaires with enclosed letters explaining the purpose of the study were sent in May 2013 to nursing managers or administrators of the 750 aged care facilities we surveyed. After the nurses or care workers agreed to participate, they were asked to complete the questionnaire within 2 weeks, place the completed questionnaire in an envelope without revealing their name, and return it to the researchers.

Ethical Considerations

Each facility's nursing managers, administrators, and participating nurses and care workers were provided with a written letter stating the purpose and methods of the study; the risks, benefits, and voluntary nature of participation; and their right to refuse participation. Nurses and care workers were regarded as having consented to participate in the study when they completed and returned the questionnaire, which was anonymous, to the researchers. The study was approved by the research ethics committee of Gunma University.

Data Analysis

Because a majority of the data were not normally distributed, data analysis was conducted via nonparametric statistical methods. The nurses' and care workers' characteristics and assessment strategies were compared using the Mann-Whitney *U* test or χ^2 test. The prevalence of pain in general, chronic pain, and unknown pain status was calculated via the estimated numbers of residents with pain in general, chronic pain, or unknown pain status divided by the total number of residents in the wards, and multiplied by 100. Spearman's rank correlation coefficient or the Mann-Whitney *U* test was used to assess the associations between nurses' and care workers' estimations of pain and their characteristics, perceptions regarding pain and pain care, and implementation of pain assessment strategies. All data were analyzed using IBM SPSS Statistics 22.

RESULTS

In all, 263 (17.5%) questionnaires were returned; 147 (55.9%) were from nurses and 116 (44.1%) were from care workers. Table 1 displays the nurses' and care workers' demographic information, as well as the characteristics of their wards and facilities. A majority of the nurses were women (n = 136, 92.5%), whereas just over half of the care workers were women (n = 68, 58.6%). Median years of experience as a nurse or care worker were 23 years and 11 years, respectively. Statistically significant differences between nurses and care workers were observed in terms of their age and work experience ($p < .001$). A policy or guidelines regarding pain management were available at 27 (10.7%) facilities, while in-service pain education within the past year was provided at 26 (10.3%) facilities. The median numbers of residents and residents receiving respite care were 49 and 1 for nurses and 47 and 1 for care workers, respectively.

Care workers' estimations of pain prevalence among residents in their ward (median: 29.4%) were significantly higher than those of nurses (11.6%, $p < .001$). Furthermore, care workers' estimations of the prevalence of chronic pain among residents in their wards (median: 26.7%) were significantly higher than those of nurses (15.8%, $p < .001$). However, there was no significant difference between nurses and care workers ($p = .626$) in their estimations of the number of residents whose pain status was unknown.

Assessment Strategies Employed by Nurses and Care Workers

Implementation of pain assessment strategies among nurses and care workers was examined (Table 2). "Using a pain map to identify the location of pain," "considering the use of screening tools to detect neuropathic pain," "identifying validated assessment tools that the resident can easily use," and "considering the levels of residents' physical functions, and using scales under good lighting with large printed letters" were used less frequently by both nurses and care workers compared with other strategies.

Perceptions Regarding Pain and Pain Care

Eighty-two (57.0%) nurses and 72 (63.2%) care workers strongly disagreed or disagreed with the statement, "older adults feel less pain than do younger people" (Table 3). Sixty-six nurses (45.5%) and 28 care workers (24.6%) agreed or strongly agreed with the statement, "I have enough knowledge and skills to assess and manage residents' pain."

Relationship Between Estimated Pain Prevalence and Relevant Pain Assessment Strategies

The nurses who observed signs of pain among their residents during the previous month, who considered various explanations for the pain experienced by older adults, and who used a multidisciplinary teamwork approach in assessing and managing pain had significantly higher estimations of the prevalence of pain than those who did not (p = .042, .007, and .007, respectively; Table 4). For care workers, those who considered various explanations for the pain had a significantly higher estimation of the prevalence of pain than those who did not ($p = .043$).

Relationship Between Estimated Chronic Pain Prevalence and Relevant Pain Assessment Strategies

The nurses who searched for nonverbal and behavioral signs of pain among their residents during the previous month, who considered various explanations for pain among older people, and who applied a multidisciplinary approach to pain assessment and management had significantly higher estimations of the prevalence

Table 1.
Characteristics of participants, facilities and wards

	Nurses (n = 147)				Care Workers (n = 116)				
	n	%	Medi	Interquartile Range	n	%	Medi	Interquartile Range	p*
Participants									
Age (y)	147		49.0	41.0-57.0	115		37.0	32.0-45.5	<.001
Work experience as a nurse or care worker (y)	147		23.0	15.0-30.0	116		11.0	8.0-15.0	<.001
Sex									
Female	136	92.5			68	58.6			
Male	11	7.5			48	41.4			
License†									
Registered nurse	124	84.4			-				
Assistant nurse	47	32.0			-				
Certified care worker	2	1.4			111	95.7			
Home helper	-				75	64.7			
Care manager	38	25.9			-				
Facilities									
Existence of the facility (y)	139		12.0	7.0-16.0	110		13.0	9.0-16.0	.355
Policies regarding pain management									
Not available	130	90.9			95	87.2			
Available	13	9.1			14	12.8			
In-service pain education within a year									
No	132	91.0			130	90.9			
Yes	13	9.0			13	9.1			
Wards									
Types of ward									
General	95	64.6			87	75.0			
Dementia care	24	16.3			12	10.3			
Small unit‡	13	8.8			8	6.9			
Other/No answer	15	10.2			9	7.8			
Number of nurses									
Full time	144		5.0	3.0-8.0	110		4.5	3.0-7.0	.037
Part time	136		2.0	1.0-4.0	102		1.0	1.0-4.0	.200
Number of residents	146		49.0	39.0-60.0	116		47.0	37.0-52.0	.055
Number of residents receiving respite care	140		1.0	0-4.0	108		1.0	0-3.0	.887
Estimated prevalence of residents with pain	141		11.6	6.1-28.8	109		29.4	16.5-56.8	<.001
Estimated prevalence of residents with chronic pain	139		9.4	4.0-20.6	108		15.5	7.5-35.1	<.001
Estimated rate of the residents whose pain status was unknown	133		14.0	5.3-37.9	98		16.5	6.1-37.5	.626

*The two groups of nurses and care-workers were compared using Mann–Whitney *U* test.
†Multiple answer questions.
‡A small unit often consists of <10 residents and provides their own kitchen and day room in the units.

of chronic pain than did other nurses (p = .027, .010, and .035, respectively; Table 5). For care workers, those who directly asked residents about their pain had a significantly higher estimation of the prevalence of chronic pain than did those who did not use this strategy (p = .027).

Relationship Between the Number of Residents with Unknown Pain Status and Relevant Pain Assessment Strategies

Overall, a statistically significant but weak negative correlation between the number of residents receiving respite services and the number of residents with

Table 2.
Implementation of Assessment Strategies among Nurses and Care Workers

		Nurse				Care Workers				
		Implemented within Last Month				Implemented within Last Month				
		No		Yes		No		Yes		
		n	%	n	%	n	%	n	%	p*
1	Using a two-part approach: observation techniques and residents' pain self-reports.	10	6.9	135	93.1	10	8.8	103	91.2	.641
2	Searching for nonverbal and behavioral signs of pain.	5	3.4	140	96.6	5	4.4	108	95.6	.752
3	Conducting regular pain assessments such as upon admission, during periodic scheduled assessments, and whenever a change occurs in residents' conditions.	40	27.6	105	72.4	45	39.8	68	60.2	.045
4	Considering various pain explanations by older people.	18	12.5	126	87.5	31	27.4	82	72.6	.004
5	Asking residents directly about pain because they might not report their pain.	9	6.3	135	93.8	13	11.5	100	88.5	.178
6	Attempting to assess pain by directly querying the patients who have cognitive impairments.	3	2.1	141	97.9	10	8.8	103	91.2	.020
7	Evaluating pain characteristics, location, duration, and precipitating and relieving factors.	16	11.0	129	89.0	31	27.9	80	72.1	.001
8	Conducting pain assessment despite reporting slight pain.	49	33.8	96	66.2	57	51.8	53	48.2	.005
9	Using a pain map to identify the location of the pain.	123	84.8	22	15.2	101	90.2	11	9.8	.260
10	Assessing biological types of pain and contributing factors and barriers to treatment.	71	49.7	72	50.3	84	75.7	27	24.3	<.001
11	Considering the use of screening tools to detect neuropathic pain.	131	92.9	10	7.1	105	94.6	6	5.4	.796
12	Identifying validated self-assessment tools that the residents can easily use.	126	88.1	17	11.9	103	92.0	9	8.0	.405
13	Considering the levels of residents' physical functions, and using scales under good lighting and with large printed letters.	119	82.6	25	17.4	88	79.3	23	20.7	.521
14	Repeating instructions and giving adequate time to respond when residents have cognitive impairments.	58	40.0	87	60.0	51	45.5	61	54.5	.377
15	Offering additional assistance via self-reports using suitably adapted scales and facilitation by skilled professionals when residents have moderate to severe communication problems.	81	55.9	64	44.1	70	61.9	43	38.1	.373
16	Monitoring various factors related to chronic pain on an ongoing basis.	35	24.1	110	75.9	45	39.8	68	60.2	.010
17	Including the evaluation of effectiveness of past pain-relieving treatments.	72	49.7	73	50.3	75	66.4	38	33.6	.008
18	Identifying concerns regarding current pain treatment and health of residents.	35	24.6	107	75.4	28	25.5	82	74.5	.885
19	Using multidisciplinary teamwork for pain assessment and management.	45	31.3	99	68.8	23	21.1	86	78.9	.086

*χ^2 tests.

Table 3.
Participants' Perception Regarding Pain and Pain Care

	Nurses								Care Workers							
	Strongly Disagree		Disagree		Agree		Strongly Agree		Strongly Disagree		Disagree		Agree		Strongly Agree	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Older adults feel less pain than younger people	22	15.3	60	41.7	41	28.5	21	14.6	32	28.1	40	35.1	30	26.3	12	10.5
I do not have enough time to provide care for residents in pain	9	6.2	45	30.8	68	46.6	24	16.4	6	5.2	20	17.4	60	52.2	29	25.2
I am satisfied with the pain care strategies that were provided to residents in my facility	34	23.3	70	47.9	35	24.0	7	4.8	30	26.3	65	57.0	17	14.9	2	1.8
I think that residents in my ward need chronic pain management strategies.	4	2.8	36	25.0	70	48.6	34	23.6	2	1.8	20	17.7	50	44.2	41	36.3
I have enough knowledge and skills to assess and manage residents' pain	18	12.4	61	42.1	59	40.7	7	4.8	39	34.2	47	41.2	26	22.8	2	1.8
I have the doctors, nurses, or other health professionals whom I could ask about pain management strategies for residents when I need	6	4.1	23	15.8	37	25.3	80	54.8	2	1.7	9	7.8	41	35.7	63	54.8

unknown pain status was observed ($r = -0.23$; $p < .05$; Table 6). Among care workers, those who received in-service pain education (n = 10) had a significantly higher estimation of the number of residents whose pain status was unknown than did those who did not use this strategy ($p = .044$). Care workers who considered various explanations for residents' pain had a significantly lower estimation of the number of residents whose pain status was unknown than those who did not use this strategy ($p = .046$). However, no significant relationship was observed between nurses' estimations of the prevalence of unknown pain status and pain assessment strategies they employed.

DISCUSSION

The results of this study indicated that nurses and care workers tended to estimate the prevalence of pain in general as well as chronic pain to be as low as 10% to 30% among residents of aged care facilities. However, care workers' estimations of the prevalence of pain and chronic pain among residents were significantly higher than those of nurses. The prevalence of residents' self-reported pain has been found to be 60% to 80% in previous studies of long-term care residents (van Herk et al., 2009), while proxy reports place the prevalence at around 50% (Takai et al., 2013; Zwakhalen, Koopmans, Geels, Berger, & Hamers, 2009); thus, care workers' estimations might be relatively closer to residents' self-reported pain prevalence, despite the low estimations found in the current study. Both nurses and care workers in this study generally did not use tools or scales to support their pain assessment, which potentially caused these low estimations. Improvements in assessments should be undertaken to comprehend pain problems among residents.

A lower estimation of the prevalence of pain in general and that of chronic pain by nurses, as compared with care workers, was found in this study, although nurses reported more frequently performing most of the assessment strategies. One potential explanation might be that the nurses were older and thus had worked with slightly more residents than did the care workers. Additionally, the nurses might have been in a supervisory position in the ward, which would have made it difficult for them to directly assess and comprehend the residents' pain status. Care workers are normally involved with direct care related to residents' daily living, and thus may have been more likely to encounter residents complaining of pain. Although the nurses may have had limited accessibility to the residents, they were responsible for providing medical treatment support, the administration of medication, monitoring residents' health status, and ensuring

Table 4.
Relationship between Estimated Prevalence of Pain in General among Nurses and Care Workers and Factors Related to It

	Nurses					Care Workers				
		Prevalence (%)					Prevalence (%)			
	n	Medi	Interquartile range	r*	p	n	Medi	Interquartile range	r*	p
Assessment strategies										
Searching for nonverbal and behavioral signs of pain.										
No	5	2.8	0.0-6.7		.042†	5	35.3	20.0-37.1		.947†
Yes	134	12.7	6.3-28.8			102	29.2	16.4-56.8		
Considering various pain explanations by older people.										
No	18	7.4	3.3-15.4		.007†	30	23.5	11.7-38.5		.043†
Yes	120	14.4	6.4-29.9			77	33.3	17.9-62.7		
Using multidisciplinary teamwork for pain assessment and management.										
No	42	7.7	4.0-19.6		.007†	21	24.5	12.5-50.0		.181†
Yes	96	15.9	6.8-29.9			81	33.3	17.2-57.7		
Facilities										
Policies regarding pain management										
No	125	13.3	6.7-28.8		.051†	91	29.2	16.6-52.1		.943†
Yes	12	6.2	5.5-9.3			12	26.7	10.5-78.4		
In-service education within a year										
No	127	11.6	6.6-28.1		.822†	90	29.2	16.4-51.7		.905†
Yes	12	12.7	5.5-30.0			11	23.8	12.3-57.2		
Number of										
Total residents	141			–0.17	.042	109			–0.22	.024
Respite care residents	136			0.04	.661	104			–0.07	.490
Full-time nurses	139			–0.28	<.001	106			–0.16	.100
Experience as a nurse or a care worker (y)	141			–0.08	.348	109			–0.07	.463
Perceptions regarding pain and pain care‡										
Older adults feel less pain than younger people	138			–0.12	.151	108			–0.13	.172
I do not have enough time to provide care for residents in pain	140			0.19	.022	109			0.10	.294
I am satisfied with pain care strategies that were provided to residents in my facility	140			–0.16	.058	109			–0.09	.361
I think that residents in my ward need chronic pain management strategies.	138			0.27	.002	107			–0.11	.262
I have enough knowledge and skills to assess and manage residents' pain	139			–0.05	.582	109			0.04	.683
I have the doctors, nurses, or other health professionals whom I could ask about pain management strategies for residents when I need	140			–0.13	.115	109			–0.10	.283

*Spearman's rank correlation coefficient.

†The two groups of yes and no were compared using Mann-Whitney *U* test.

‡Perceptions regarding pain and pain care were entered as an ordinal variable, *strongly disagree* (1) to *strongly agree* (4).

Table 5.
Relationship between Estimated Chronic Pain Prevalence among Nurses and Care Workers and Factors Related to It

	Nurses					Care Workers				
	Prevalence (%)					Prevalence (%)				
	n	Medi	Interquartile range	r*	p	n	Medi	Interquartile range	r*	p
Assessment strategies										
Searching for nonverbal and behavioral signs of pain.										
No	5	0.0	0.0-0.0		.027†	5	10.0	7.1-35.3		.623†
Yes	132	10.0	4.2-21.2			101	15.6	7.5-33.3		
Considering various pain explanations by older people.										
No	18	5.2	0.0-12.6		.010†	30	12.7	5.6-29.2		.158†
Yes	118	10.6	4.3-22.2			76	20.0	7.5-39.2		
Asking residents directly about pain because they might not report their pain.										
No	9	19.4	9.1-20.8		.333†	13	12.2	2.6-20.0		.027†
Yes	127	8.8	4.0-21.0			93	17.2	7.5-37.1		
Using multidisciplinary teamwork for pain assessment and management.										
No	41	6.6	2.0-15.0		.035†	21	12.2	7.5-20.0		.065†
Yes	95	11.1	5.2-21.7			80	20.0	7.6-37.8		
Facilities										
Policies regarding pain management										
No	123	10.0	4.1-20.6		.210†	90	15.2	7.5-33.3		.860†
Yes	12	5.6	3.8-8.3			12	16.1	3.2-64.6		
In-service education										
No	126	9.5	4.1-20.8		.544†	90	15.5	7.5-33.3		.421†
Yes	11	7.7	3.8-15.3			10	10.0	7.1-38.5		
Number of										
Total residents	139			–0.18	.036	108			–0.14	.139
Respite care residents	135			0.03	.702	103			–0.06	.561
Full-time nurses	137			–0.27	.002	105			–0.06	.518
Experience as a nurse or care worker (y)	139			–0.02	.832	108			–0.09	.374
Perceptions regarding pain and pain care‡										
Older adults feel less pain than younger people	136			–0.16	.071	107			–0.12	.234
I do not have enough time to provide care for residents in pain	138			0.18	.033	108			0.16	.103
I am satisfied with pain care strategies that were provided to residents in my facility	138			–0.13	.132	108			–0.11	.274
I think that residents in my ward need chronic pain management strategies.	136			0.26	.003	106			–0.02	.830
I have enough knowledge and skills to assess and manage residents' pain	137			–0.03	.737	108			–0.01	.958
I have the doctors, nurses, or other health professionals whom I could ask about pain management strategies for residents when I need	138			–0.16	.059	108			–0.01	0.887

*Spearman's rank correlation coefficient.
†The two groups of yes and no were compared using Mann-Whitney *U* test.
‡Perceptions regarding pain and pain care were entered as an ordinal variable, *strongly disagree* (1) to *strongly agree* (4).

TABLE 6.
Relationship between Percentages of the Residents Whose Pain Status was Unknown, among Nurses and Care Workers and Factors Related to It

	Nurses					Care Workers				
	Prevalence (%)					Prevalence (%)				
	n	Medi	Interquartile Range	r*	p	n	Medi	Interquartile Range	r*	p
Assessment strategies										
Conducting regular pain assessments such as upon admission, during periodic scheduled assessments, and whenever a change occurs in residents' conditions.										
No	36	25.0	7.7-56.0		0.147†	37	25.0	9.3-47.6		.039†
Yes	95	13.7	3.4-30.8			59	12.8	5.5-25.5		
Considering various pain explanations by older people.										
No	16	34.6	1.4-86.1		0.254†	30	25.0	11.8-45.8		.046†
Yes	114	12.4	5.3-34.0			66	12.4	5.7-31.3		
Evaluating pain characteristics, location, duration, and precipitating and relieving factors.										
No	16	30.4	10.2-75.0		0.082†	26	28.9	11.4-50.0		.005†
Yes	115	11.5	4.6-35.1			70	12.6	5.5-29.4		
Repeating instructions and giving adequate time to respond when residents have cognitive impairments.										
No	53	14.0	4.1-37.9		0.864†	43	20.8	11.0-44.5		.018†
Yes	78	12.9	5.9-38.0			54	11.6	4.6-25.0		
Monitoring various factors related to chronic pain on an ongoing basis.										
No	31	21.9	1.4-47.2		0.696†	38	25.3	11.1-48.3		.005†
Yes	100	11.3	5.6-36.8			59	12.2	4.4-24.4		
Including the evaluation of effectiveness of past pain relieving treatments.										
No	62	15.7	6.0-40.8		0.300†	64	20.0	9.1-42.8		.033†
Yes	69	11.5	2.7-37.5			33	11.1	4.6-22.2		
Facilities										
Policies regarding pain management										
No	117	14.3	5.9-37.9		0.264†	80	16.5	7.9-36.3		.711†
Yes	12	9.9	0.0-32.1			12	27.2	4.0-55.0		
In-service education										
No	120	13.5	5.0-38.0		0.730†	82	14.6	6.1-34.0		.044†
Yes	11	23.5	10.6-25.3			10	34.4	25.0-43.2		
Number of										
Total residents	133			−0.07	0.420	98			0.08	.454
Respite care residents	129			−0.23	0.008	95			−0.23	.024
Full-time nurses	131			0.16	0.073	95			0.24	.020
Experience as a nurse or care worker (y)	133			−0.02	0.802	98			−0.18	.074
Perceptions regarding pain and pain care‡										
Older adults feel less pain than younger people	130			−0.08	0.360	98			−0.12	.238
I do not have enough time to provide care for residents in pain	132			0.10	0.246	98			−0.17	.100

I am satisfied with the pain care strategies that were provided to residents in my facility	132	−0.07	0.421	98	−0.06	.532
I think that residents at my ward need chronic pain management strategies.	130	0.27	0.002	96	0.01	.901
I have enough knowledge and skills to assess and manage residents' pain	131	−0.06	0.525	98	−0.17	.102
I have the doctors, nurses, or other health professionals whom I could ask about pain management strategies for residents when I need	132	−0.13	0.130	98	0.05	.617

*Spearman's rank correlation coefficient.
†The two groups of yes and no were compared using Mann-Whitney *U* test.
‡Perceptions regarding pain and pain care was entered as an ordinal variable, *strongly disagree* (1) to *strongly agree* (4).

appropriate documentation (Takemura, Kanda, Matsumoto, & Yamagishi, 2002). Thus, it is important for nurses to appropriately comprehend and efficiently assess residents' pain status. Additionally, those nurses who employed a multidisciplinary approach, considered to be relatively important to aged care (Takemura et al., 2002), had a higher estimation of the prevalence of pain than did nurses who did not. Collaboration between nurses and care workers at aged care facilities may be necessary, as this would allow sufficient sharing and discussion of residents' pain status.

We noted that different assessment strategies between nurses and care workers were associated with the estimated prevalence of pain in residents. Care workers' estimations of the prevalence of pain in general and chronic pain were associated with directly asking residents about their pain. By contrast, nurses' estimations were associated with observations of residents' behaviors and performing multidisciplinary teamwork. Although both strategies are important, self-reports should be considered the gold standard for identifying pain because pain is a subjective experience (AGS Panel on Persistent Pain in Older Persons, 2002; Pautex & Gold, 2006). However, because most residents of long-term care facilities in Japan have some degree of cognitive impairment, careful observations of residents' behaviors also should be used to assess their pain (Wheeler, 2006). Thus, nurses and care workers may need to perform more comprehensive pain assessments by using information from both self-reports and direct observations, and by sharing that information with each other.

The number of residents with unknown pain status estimated by care workers was associated with the assessment strategies of monitoring various factors related to chronic pain, evaluating pain characteristics, and evaluating the effectiveness of pain relief treatments. These assessment strategies are important in determining the types of pain residents' may experience and appropriate pain care (Institute for Clinical Systems Improvement, 2011), and thus should be implemented further by care workers. However, in this study, we noted that few of the facilities provided in-service education related to pain care or had policies regarding pain management. Thus, appropriate in-service education and policies regarding pain at long-term care facilities need to be implemented.

This study had several limitations. First, the response rate was relatively low, reducing the generalizability of the study. Second, we asked nursing managers or administrators from the target facilities to consider participation in this study and to choose the nurses and care workers who would answer the questionnaires. This procedure might have caused bias insofar as the participants chosen might have been more aware of pain management strategies than their unchosen co-workers. Third, we asked participants to estimate the prevalence of pain in general and chronic pain among their residents. However, it may be hard to detect chronic pain in residents with cognitive impairment. The estimates of prevalence in this study should therefore be carefully interpreted.

Implications for Nursing Education, Practice, and Research

Nurses' and care workers' estimations of pain prevalence were relatively low, and may underrepresent the actual numbers of residents in pain or chronic pain. The current results indicate that nurses and care workers would benefit from education on performing proper and efficient pain assessment for their residents. The use of tools and scales to assess pain status and disabilities related to pain should be facilitated, including observational pain assessment scales, such as the Abbey Pain Scale (Abbey et al., 2004; Takai et al., 2010) and the Modified Resident Verbal Brief Pain Inventory (Auret et al., 2008), which also evaluates the extent to which pain interferes with daily living.

The pain assessment strategies we included were from a pain management guideline developed through the amalgamation of 16 guidelines and based on evidence from previous studies. However, evidence for the efficacy of these pain assessment strategies is limited (Hadjistavropoulos et al., 2007). It is possible that some effective assessment strategies might have been inadvertently excluded from this study. Assessment strategies that could improve the detection of pain in older residents should be explored further in future research.

CONCLUSIONS

This study explored differences between nurses' and care workers' estimations of the prevalence of pain in general and chronic pain among residents in the wards in Japanese long-term care facilities. We found that these prevalence estimates, according to both nurses and care workers, were low. Additionally, pain assessment strategies, such as nurses' multidisciplinary approaches to pain management, influenced estimations of the prevalence of pain. Improvements in current pain assessment procedures are necessary to better comprehend residents' pain and needs for care.

Acknowledgments

The authors are extremely grateful to all of the study participants.

REFERENCES

Abbey, J., Piller, N., De Bellis, A., Esterman, A., Parker, D., Giles, L., & Lowcay, B. (2004). The Abbey Pain Scale: A 1-minute numerical indicator for people with end-stage dementia. *International Journal of Palliative Nursing, 10*(1), 6–13.

AGS Panel on Persistent Pain in Older Persons. (2002). The management of persistent pain in older persons. *Journal of American Geriatrics Society, 50*, 205–224.

Akamine, I., & Masaki, S. (2002). Tiiki Zaijyu Koureisya Heno Pein Manejimento No Dounyu [Introduction of pain management for the elderly community residents]. *Journal of Okinawa Prefectual College of Nursing, 3*, 25–31.

Anzai, S., Shiba, Y., & Haga, H. (2012). Chiikizaijyukoureisyano Undoukinou Teikani Kanrensuru Sintaino Itami [Association between physical function and musculoskeletal pain in community-dwelling elderly people]. *Nippon Ronen Igakkai Zasshi. Japanese Journal of Geriatrics, 49*(2), 234–240.

Auret, K. A., Toye, C., Goucke, R., Kristjanson, L. J., Bruce, D., & Schug, S. (2008). Development and testing of a modified version of the Brief Pain Inventory for use in residential aged care facilities. *Journal of the American Geriatrics Society, 56*(2), 301–306.

Boerlage, A. A., van Dijk, M., Stronks, D. L., de Wit, R., & van der Rijt, C. C. (2008). Pain prevalence and characteristics in three Dutch residential homes. *European Journal of Pain, 12*(7), 910–916.

British Pain Society and British Geriatrics Society. (2007). The assessment of pain in older people 2007. Available at: http://www.bgs.org.uk/Publications/Publication%20Downloads/Sep2007PainAssessment.pdf. Accessed December 1, 2013.

Cadogan, M. P., Edelen, M. O., Lorenz, K. A., Jones, M., Yosef, J., Hascall, T., Simon, B., Harker, J. O., Ferrell, B., & Saliba, D. (2008). The relationship of reported pain severity to perceived effect on function of nursing home residents. *Journals of Gerontology. Series A, Biological Sciences and Medical Sciences, 63*(9), 969–973.

Hadjistavropoulos, T., Herr, K., Turk, D. C., Fine, P. G., Dworkin, R. H., Helme, R., Jackson, K., Parmelee, P. A., Rudy, T. E., Lynn Beattie, B., Chibnall, J. T., Craig, K. D., Ferrell, B., Fillingim, R. B., Gagliese, L., Gallagher, R., Gibson, S. J., Harrison, E. L., Katz, B., Keefe, F. J., Lieber, S. J., Lussier, D., Schmader, K. E., Tait, R. C., Weiner, D. K., & Williams, J. (2007). An interdisciplinary expert consensus statement on assessment of pain in older persons. *Clinical Journal of Pain, 23*(1 Suppl), S1–43.

Hadjistavropoulos, T., Fitzgerald, T. D., & Marchildon, G. P. (2010). Practice guidelines for assessing pain in older persons with dementia residing in long-term care facilities. *Physiotherapy Canada. Physiotherapie Canada, 62*(2), 104–113.

Institute for Clinical Systems Improvement. (2011). Health care guideline: Assessment and management of chronic pain. Avaiable at: https//www.icsi.org. Accessed December 21, 2011.

International Association for the Study of Pain. (2011). Iasp taxonomy. Available at: http://www.iasp-pain.org/Content/NavigationMenu/GeneralResourceLinks/PainDefinitions/default.htm. Accessed October 30, 2013.

Kaasalainen, S. (2007). Pain assessment in older adults with dementia: Using behavioral observation methods in clinical practice. *Journal of Gerontological Nursing, 33*(6), 6–10.

Kasai, K., & Tajita, E. (2001). Zaitkukoureisya No Syukantekikennkoukann to Itami Tono Kankei [Association between the self-assessment of health status and pain in elderly people at home]. *The Journal of the Nursing Society of the Toyama Medical and Pharmaceutical University, 4*, 13–22.

Leong, I. Y., & Nuo, T. H. (2007). Prevalence of pain in nursing home residents with different cognitive and communicative abilities. *Clinical Journal of Pain, 23*(2), 119–127.

McAuliffe, L., Nay, R., O'Donnell, M., & Fetherstonhaugh, D. (2009). Pain assessment in older people with dementia: Literature review. *Journal of Advanced Nursing, 65*(1), 2–10.

Mentes, J. C., Teer, J., & Cadogan, M. P. (2004). The pain experience of cognitively impaired nursing home residents: Perceptions of family members and certified nursing assistants. *Pain Management Nursing, 5*(3), 118–125.

Ministry of Health Labour and Welfare. (2009). Heisei 19 Nen Kaigo Sa-Bisu Sisetu/Jyugyousyo Tyousa Kekka No Jyoukyou [Survey about care service facilitis in 2007]. Available at: http://www.mhlw.go.jp/toukei/saikin/hw/kaigo/service07/index.html. Accessed December 1, 2013.

Pautex, S., & Gold, G. (2006). Assessing pain intensity in older adults. *Geriatrics Aging, 9*(6), 399–402.

Smalbrugge, M., Jongenelis, L. K., Pot, A. M., Beekman, A. T., & Eefsting, J. A. (2007). Pain among nursing home patients in the Netherlands: Prevalence, course, clinical correlates, recognition and analgesic treatment—an observational cohort study. *BMC Geriatrics, 7*, 3.

Takai, Y., & Uchida, Y. (2009). Frequency and type of chronic pain care approaches used for elderly residents in Japan and the factors influencing these approaches. *Japan Journal of Nursing Science, 6*(2), 111–122.

Takai, Y., Yamamoto-Mitani, N., Chiba, Y., Nishikawa, Y., Hayashi, K., & Sugai, Y. (2010). Abbey Pain Scale: Development and validation of the Japanese version. *Geriatrics & Gerontology International, 10*(2), 145–153.

Takai, Y., Yamamoto-Mitani, N., Chiba, Y., Nishikawa, Y., Sugai, Y., & Hayashi, K. (2013). Prevalence of pain among residents in Japan nursing homes: A descriptive Sstudy. *Pain Management Nursing, 14*(2), e1–e9.

Takai, Y., Yamamoto-Mitani, N., Fukahori, H., Kobayashi, S., & Chiba, Y. (2013). Nursing ward managers' perceptions of pain prevalence at the aged-care facilities in Japan: A nationwide survey. *Pain Management Nursing: Official Journal of the American Society of Pain Management Nurses, 14*(3), e59–e66.

Takai, Y., Yamamoto-Mitani, N., & Ko, A. (2013). Prevalence of and factors related to pain among elderly Japanese residents in long-term healthcare facilities. *Geriatrics & Gerontology International, 14*(2), 481–489.

Takemura, Y., Kanda, K., Matsumoto, A., & Yamagishi, M. (2002). Role expectations of nurses in health service facilities for the elderly. *Nursing & Health Sciences, 4*(3), 73–83.

van Herk, R., Boerlage, A. A., van Dijk, M., Baar, F. P., Tibboel, D., & de Wit, R. (2009). Pain management in Dutch nursing homes leaves much to be desired. *Pain Management Nursing, 10*(1), 32–39.

Welfare and Medical Service Agency. (2011). Kaigo Roujin Hoken Sisetuno Keiei Jyoutai [Financial conditions of geriatric health care facilities]. Available at: http://hp.wam.go.jp/useful/tabid/1194/Default.aspx. Accessed February 23, 2014.

Wheeler, M. S. (2006). Pain assessment and management in the patient with mild to moderate cognitive impairment. *Home Healthcare Nurse, 24*(6), 354–359.

Won, A. B., Lapane, K. L., Vallow, S., Schein, J., Morris, J. N., & Lipsitz, L. A. (2004). Persistent nonmalignant pain and analgesic prescribing patterns in elderly nursing home residents. *Journal of the American Geriatrics Society, 52*(6), 867–874.

Young, J. L., Horton, F. M., & Davidhizar, R. (2006). Nursing attitudes and beliefs in pain assessment and management. *Journal of Advanced Nursing, 53*(4), 412–421.

Zanocchi, M., Maero, B., Nicola, E., Martinelli, E., Luppino, A., Gonella, M., Gariglio, F., Fissore, L., Bardelli, B., Obialero, R., & Molaschi, M. (2007). Chronic pain in a sample of nursing home residents: Prevalence, characteristics, influence on quality of life (Qol). *Archives of Gerontology and Geriatrics, 47*(1), 121–128.

Zwakhalen, S. M., Koopmans, R. T., Geels, P. J., Berger, M. P., & Hamers, J. P. (2009). The prevalence of pain in nursing home residents with dementia measured using an observational pain scale. *European Journal of Pain, 13*(1), 89–93.

Geriatr Gerontol Int 2014; **14:** 481–489

ORIGINAL ARTICLE: SOCIAL RESEARCH, PLANNING AND PRACTICE

Prevalence of and factors related to pain among elderly Japanese residents in long-term healthcare facilities

Yakari Takai,[1] Noriko Yamamoto-Mitani[2] and Ayako Ko[3]

[1]Graduate School of Health Sciences, Gunma University, Maebashi, Gunma, [2]Department of Adult Nursing/Palliative Care Nursing, Division of Health Sciences and Nursing, Graduate School of Medicine, the University of Tokyo, and [3]Department of Gerontological Nursing, Graduate School of Health Care Sciences, Tokyo Medical and Dental University, Tokyo, Japan

Aim: We aimed to examine the pain prevalence among residents who stayed at healthcare facilities for the elderly requiring long-term care in Japan, and explore factors related to self-reported pain.

Methods: This was a cross-sectional study. All residents in nine healthcare facilities in Japan were asked to participate in the present study, with the exclusion of short-term and temporary residents. Demographic data were collected from participating residents' medical records. The residents were evaluated using the Barthel Index, the Folstein Mini-Mental State Examination and Self-Rated Health measures. After/during patients underwent a body movement protocol, self-reported pain/Abbey Pain Scale scores were obtained. The χ^2-test, *t*-test and logistic regression analyses were carried out to identify factors related to pain.

Results: Data were obtained from 246 residents. The prevalence of pain among the residents was 47.2%. Self-rated health status and history of fracture were significantly associated with self-reported pain. Logistic regression analysis showed that self-rated health status (odds ratio [OR] 0.50, 95% confidence interval (CI) 0.28–0.88), mental health diagnoses (OR 9.18, 95%CI 1.27–66.52) and respiratory diagnoses (OR 0.16; 95%CI 0.03–0.97) were associated with pain experienced by residents.

Conclusions: Nearly half of the residents suffered from pain on movement. The pain of these elderly residents should be managed in order to improve their health status. **Geriatr Gerontol Int 2014; 14: 481–489.**

Keywords: aged care, dementia, pain, prevalence, rehabilitation.

Introduction

Pain is a common and serious problem among older adults. In Japan, 70% of older adults living at home experience pain that keeps them indoors.[1,2] Furthermore, 46.2% of older nursing home residents experience pain.[3] Pain can also lead to depression, reduced physical ability and poor sleep quality.[4–6] Because pain can cause older adults to withdraw from social interaction and physical activities, the condition must be identified accurately and managed appropriately.

Pain is a subjective experience. Healthcare workers should tailor their approach to pain management according to the pain reported by a given individual. However, older adults often hesitate to report pain, because they consider complaining about pain to be inappropriate or believe that pain is a normal part of aging.[7] Older adults often have physical disabilities and/or cognitive impairments; these factors can further impede older adults' abilities and beliefs to report pain on their own behalf.

Wide ranges of pain prevalence (3.7% to 79.5%[8]) and factors related to pain have been reported among older nursing home residents. The variation among these estimates could stem from methodological differences, such as the time frame of pain detection (e.g. "last week"[4] *vs* "at the moment"[9]) or the methods used to quantify pain (e.g. self-reported[7] *vs* proxy assessment[8,10]). Self-reported pain has been considered the gold standard in pain evaluation; however, more than 90% of residents in the aged-care system have cognitive impairment.[11] To maximize the accuracy of pain reports from residents, subjects should be interviewed soon after the painful episode that is the subject of the investigation.[12] Proxy pain assessment could also help to

Accepted for publication 10 April 2013.

Correspondence: Ms Yakari Takai DNSc RN, Graduate School of Health Sciences, Gunma University, 3-39-22 Showa-machi, Maebashi, Gunma 371-8514, Japan. Email: takaiyuka@gunma-u.ac.jp

obtain pain status for the residents who could not report their pain.

In 2000, Japan established a long-term care insurance system for older adults in order to provide services that would allow these individuals to stay in their homes for as long as possible. The healthcare facilities for the elderly requiring long-term care (HCF: *kaigoroujinhokensisetsu*) established under this system provide rehabilitation and extended-care services to older adults discharged from hospital. Expectations with regard to the roles and services of HCF have increased with time.

Previous studies addressed some concerns regarding pain among HCF residents. A qualitative study reported that residents stated that they avoided walking around by themselves and preferred to use a wheelchair because of fear of pain.[13] Another study reported that nursing ward managers of the HCF estimated lower pain prevalence among the residents (22.3%)[14] than the results of studies carried out in the community.[1,3] However, few studies have examined pain prevalence by self-reports/direct observation of the residents and pain-related problems. These issues must be investigated thoroughly in order to develop adequate and necessary pain management systems, and to facilitate rehabilitation. The present study is the first to examine the prevalence of pain among HCF residents in Japan and to explore factors related to self-reported pain.

Methods

Participants and settings

HCF access was determined by convenience sampling. Data were collected from nine HCF in four prefectures of the Kanto region in Japan. These facilities had the capacity to house 50–165 residents (mean 92.7 residents). No significant differences in age or level of care required were found among samples at the facilities.

Because of the high prevalence of cognitive impairment among aged care residents in Japan,[11] we asked the HCF staff to send letters to family members or guardians of all residents ($n = 736$) asking for their consent to participate in the study. This process required 1 month; therefore, 98 residents who planned to stay at the facility for less than 1 month or who were discharged before the start of the research study were excluded. Ultimately, 296 family members agreed to participate. Among this group, 50 residents refused to participate, 19 were admitted to the hospital or discharged from the facilities, and 14 residents had health or other concerns that prevented them from participating in the study. The median number of participants at each of the nine facilities was 27 (range 18–48).

Data collection

Residents' characteristics

The demographic data collected from the residents' medical records included age, sex, care requirement levels as specified by Japanese long-term care insurance law, length of stay and the duration for which residents had availed facility services. Researchers obtained each patient's diagnoses from the primary doctors' and nurses' records. The number of diagnoses ascribed to each patient was counted.[10] Diagnoses were classified according to the body system involved. Diagnoses related to cognitive impairment were identified. Diagnoses related to pain, such as a history of fracture, hip prosthesis or open reduction, arthritis, osteoporosis and cancer,[9,15] and conditions such as paralysis[16] and joint contracture[17] were also identified. The medication usage and specific care required by each patient for the 6 h preceding a body movement protocol were identified from residents' medical records, nursing charts and associated medical prescriptions.

The level of activities of daily living (ADL) was measured according to the Barthel Index (BI). The BI score ranges from 0 to 100, with higher scores indicating greater ability.[18] Previous research has shown the reliability and validity of the Japanese version of the BI.[19]

The Japanese version of the Folstein Mini-Mental State Examination (MMSE) was used to characterize each participant's cognitive status. MMSE scores range from 0 to 30, with lower scores indicating inferior cognitive ability.[20] To examine residents who did not cooperate with the MMSE test, and those who were illiterate, blind or hard of hearing, the Global Deterioration Scale was also used to determine the severity of cognitive impairment.[21] This scale is highly reliable.[22–24] Researchers' observations and information gathered from staff interviews were used to supplement these scores.

Depressive status was measured using the 15-item Geriatric Depression Scale (GDS-15). The GDS-15 is a short-form interview used to assess depression among older adults. The associated scores range from 0–15, with a score of ≥5 indicating depression.[25] Residents were evaluated using the GDS-15 if their MMSE scores were above 15. This approach maintained the sensitivity (84%) and specificity (91%) of the GDS-15.[26]

The Self-Rated Health (SRH)[5,27] measure was used to quantify self-estimated health status among residents. The SRH is frequently used as a substitute for clinical health status or as a measure of the health-related quality of life.[28] Each resident rated his or her health status on a five-point Likert scale ranging from "bad" (1) to "excellent" (5).

Owing to the established relationship between chronic pain and body mass index (BMI),[29] BMI was also calculated. BMI was calculated as weight in kilograms divided by the square of a resident's height in meters. This information was gathered from the weight and height measurements recorded at the facility carried out within the previous 30 days.

Pain assessment

1. Presence of pain
   A simple question "Were you in pain during the movement?" was used to elicit a yes/no answer. If residents had difficulty hearing the question, written text was used to communicate.
2. Pain intensity
   The Verbal Descriptor Scale (VDS) was used to quantify pain intensity. The VDS involves a seven-point scale that ranges from "no pain" (0) to "pain as bad as it could be" (6).[30] This scale was chosen because it is more sensitive and reliable for use with an older population than other self-report scales, such as the visual analog scale.[31] Patients were also asked about the physical localization of their most severe pain.
3. The Japanese Version of the Abbey Pain Scale
   The Japanese version of the Abbey Pain Scale (APS-J) was used to investigate the presence of pain among residents who were not able to verbally report pain. The APS-J has been tested for its reliability and validity, and shows excellent interrater agreement and good association with self-reported pain.[32,33] Pain was rated on a four-point scale (absent = 0, mild = 1, moderate = 2, severe = 3) by observing six types of resident behaviors: vocalization, facial expression, change in body language, behavioral changes, physiological changes and physical changes.[34]

Factors related to pain and reports of pain

Residents were asked their opinions regarding statements about pain. The questions posed were developed based on the van Herk *et al.* study, as follows:[7] "Do you agree that pain is a part of aging?" and "Do you agree that you always tell staff when you suffer from pain?" Residents were also asked "Do you agree that pain should be tolerated?" and "Do you agree that you hesitate to use analgesics due to fears of the associated adverse effects?"[35,36]

Data collection

The MMSE was carried out at the research site. The BI and GDS scores determined by the researchers were confirmed by staff members familiar with a given resident's usual condition. The GDS-15 was also carried out and scored at the site; researchers read a questionnaire for participants and recorded their answers. The study period extended from October 2009 to March 2011.

Pain was evaluated using the APS-J with a body movement protocol that closely mimicked the residents' usual activities: walking in the day room or being transferred from a bed to a wheelchair by staff. The APS-J was used to acquire reliable and unequivocal non-verbal indicators of an underlying chronic pain condition.[32,37] This protocol was also designed to increase interrater agreement, and maximize the study's internal consistency.[37] Residents were asked to stand up and walk anywhere they would like to go. When a resident reached the intended place, he or she was asked to sit down on a chair. If residents were unable to move, staff helped and/or transferred them to a third location. The observation technically began when a staff member touched a resident's body, and stopped when the resident had settled in at the second destination.

The residents were asked if they experienced pain soon after completion of the movement protocol and APS-J tests. When residents could not give a clear response regarding the presence of pain or did not respond even after repeated questioning, the event was recorded as an inability to answer the question. When residents indicated that they experienced pain, they were asked about the physical localization of their pain, as well as its intensity, as measured using the VDS. The VDS questionnaire was printed using large letters for residents with hearing problems.

Data analyses

The prevalence of pain was calculated based on residents' self-reports of pain or results of the APS-J when patients were unable to report pain. The *t*-test and χ^2-test were carried out to explore the differences among residents with and without pain. Variables for the *t*-test were normally distributed or slightly skewed by visual inspection of histograms; for example, length of stay, duration of facility service utilization and Barthel Index scores, therefore we assumed that the *t*-test could be utilized. Fisher's exact test was used when necessary to account for sparse cells. A logistic regression analysis was carried out to evaluate the relationship between residents' pain and factors related to pain. The presence of pain as determined by residents' self-reports was considered as a dependent variable. Factors that could potentially relate to pain were considered as independent variables, after adjusting for confounding variables according to previous studies.[10,38] The factors considered as potential confounding variables included the number of disease diagnoses, conditions that could limit physical activities (e.g. hearing impairments and aphasias) and GDS scores. Sex was not included as a confounding variable, but was included as an independent variable, because sex was often significantly associated with pain.[10,39] Independent variables were selected as follows: factors with a high association with the dependent variable in bivariate analyses (e.g. probability value of ≤0.2) and a theoretical relevance to dependent variables, such as duration of utilization of facility services, GDS scores, hearing impairment, respiratory diagnosis, facture, arthritis, number of diagnoses and mental health diagnosis. To determine multicollinearity, associations among variables were calculated using Spearman's rank correlation coefficient. The Hosmer–Lemeshow test was used to check the model's goodness of fit. All data were analyzed using IBM SPSS Statistics19 (IBM, Tokyo, Japan).

Ethical considerations

Informed written consent was obtained from each participant's family member/guardian. The research procedure was reviewed and approved by the ethics committee of Tokyo Medical and Dental University, and the administrators of the participating HCF.

Results

In total, 246 residents participated in the present study (33.4%). The average age (mean ± SD) was 85.9 ± 8.1 years; 76.4% of the participants were female (Table 1). The average length of institutionalization was 14.1 ± 13.3 months. The mean BI, MMSE, GDS, GDS-15, SRH, and BMI scores were 32.7 ± 28.9, 10.6 ± 9.7, 5.2 ± 1.4, 7.0 ± 3.2, 3.1 ± 1.2 and 19.9 ± 3.1, respectively. The mean number of diagnoses was 3.6 ± 1.9.

Pain prevalence

Just 179 residents (72.8%) reported the presence of pain. A total of 57 residents (23.2%) reported pain on movement. The remaining residents were assessed using the APS-J, which revealed pain among an additional 59 residents (24.0%). Overall, the prevalence of pain among residents was 47.2%.

A total of 42 residents were able to characterize the intensity of the pain they experienced using the VDS: 28 residents reported slight to mild pain, five reported moderate pain and nine reported severe pain. A total of 31 residents were able to identify the most painful site: the knee (9 residents), lower extremities (9 residents), lower back (8 residents), upper extremities (2 residents), back and shoulder (2 residents), and chest (1 resident).

Factors related to pain presence

Table 2 compares characteristics of residents with and without self-reported pain. The duration of utilization of facility services, SRH, hearing impairment, respiratory diagnoses and fracture were significantly more common among residents with pain as compared with residents without pain.

A logistic regression analysis was designed to adjust for age, number of diagnoses, hearing impairment, aphasia and GDS scores (Table 3). SRH scores (odds ratio [OR] 0.50; 95% confidence interval [95% CI] 0.28–0.88), mental health (OR 9.18; 95% CI 1.27–66.52) and respiratory diagnoses (OR 0.16; 95% CI 0.03–0.97) were significantly associated with pain. The absence of multicollinearity was confirmed ($r_s < 0.32$). The Hosmer–Lemeshow test showed the model's goodness of fit ($P = 0.146$).

Residents' statements about pain

Most residents (68.5%) agreed that pain should be tolerated (Table 4). A total of 40 residents (51.9%) agreed that pain is a part of the aging process. Just 20 residents (27.4%) consistently reported their pain to a staff member. A total of 44 residents (61.1%) said that they would not hesitate to use analgesics because of fear of the associated adverse effects.

Cognitive and ADL levels in relation to self-reported pain

Cognitive state and ADL were compared between residents who reported pain, and those who did not (Table 5). The mean MMSE, GDS, and BI scores among self-reporters were 14.4 ± 8.8, 4.8 ± 1.4 and 41.3 ± 28.0, respectively. Residents who did not report pain had scores of 0.9 ± 2.6, 6.5 ± 0.5 and 10.0 ± 16.7, respectively.

Discussion

The present study examined the prevalence of pain among HCF residents and the factors related to self-reported pain. As reported in a previous study in Japan,[3] nearly half of the residents experienced pain on movement. The prevalence of self-reported pain in the present study (31.8%) was lower than that reported previously.[3] Furthermore, some residents ($n = 14$) reported moderate or severe pain; however, just 12 residents were administered analgesics or pain care before they moved. The lower prevalence of pain among the study population as compared with nursing home residents or community dwellers can be explained as follows. First, residents were often engaged in rehabilitation after discharge from an acute-care setting; therefore, the pain of these individuals might already have been under control. Alternately, people experiencing pain might have found it difficult to participate in a HCF program. Another possibility is that the pain experienced by these individuals became chronic, allowing them to adapt and find movement patterns that would not cause pain. The time frame used in the present

Table 1 Characteristics of the residents included in the study

		n	%	Mean	SD
Age (years)		246		85.9	8.1
Sex	Female	188	76.4		
	Male	58	23.6		
Care requirement level specified by Japanese long-term care Insurance law	Care level 1	21	8.5		
	Care level 2	53	21.5		
	Care level 3	56	22.8		
	Care level 4	73	29.7		
	Care level 4	43	17.5		
Length of stay (months)		244		14.1	13.3
Duration of facility service utilization (months)		232		21.4	20.8
ADL	Barthel Index (range 0–100)	246		32.7	28.9
Cognitive status	MMSE (range 0–30)	205		10.6	9.7
	Global Deterioration Scale (range 1–7)	246		5.2	1.4
Depression	GDS-15 (range 0–15)	55		7.0	3.2
Self-reported health status	SRH (range 1–5)	87		3.1	1.2
BMI		215		19.9	3.1
No. diagnoses		237		3.6	1.9
Diagnosis related to body systems (multiple answers)	Neurological system	211	85.8		
	Cardiovascular system	154	62.6		
	Musculoskeletal system	144	58.5		
	Gastrointestinal system	87	35.4		
	Endocrine system	69	28.0		
	Respiratory system	55	22.4		
	Urinary system	42	17.1		
	Mental health	24	9.8		
Diagnosis related to cognitive impairment (multiple answers)	Alzheimer's disease	47	19.1		
	Others (e.g. Lewy body dementia)	12	4.9		
	Vascular dementia	11	4.5		
	Dementia, not specified	77	31.3		
	No diagnosis of dementia	99	40.2		
Diagnosis and conditions related to pain (multiple answers)	History of fracture	92	37.4		
	Limb paralysis	75	30.5		
	Arthritis	69	28.0		
	Hip prosthesis or open reduction	52	21.1		
	Osteoporosis	32	13.0		
	Cancer	28	11.4		
Pain with movement	Self-reported pain	57	23.2		
	Self-reported no pain	122	49.6		
	No self-report and pain assessed by APS-J	59	24.0		
	No self-report and no pain assessed by APS-J	8	3.3		

ADL, activities of daily living; APS-J, Abbey Pain Scale – Japanese version; BMI, body mass index; GDS-15, Geriatric Depression Scale-15; MMSE, Folstein Mini-Mental State Examination; SD, standard deviation; SRH, self-rated health.

study could also have affected the pain prevalence. However, residents who reported moderate to severe pain might not have received adequate pain treatment. Pain detection and appropriate management should be focused in these settings.

The individuals who reported pain tended to report worse health status. This finding was similar to results published previously.[2,5] The experience of pain was also associated with mental illness in the present study. Pain can negatively impact health status through its effects on physical and psychosocial conditions.[40] This phenomenon is often described as being complex, and uses a biopsychosocial model that explains complex interactions between biological, psychological and

Table 2 Comparison between residents with or without pain by self-reports

	n	No pain Mean	SD	Pain Mean	SD	$P^{\dagger}$
Age	179	85.9	8.3	86.7	7.1	0.57
Length of stay	168	14.8	13.4	11.8	8.7	0.07
Duration of facility service utilization	168	23.4	22.6	16.8	14.7	0.03
Barthel Index	159	41.8	28.0	40.0	28.0	0.68
MMSE	147	14.1	8.8	15.0	8.8	0.58
Global Deterioration Scale	179	4.8	1.4	4.7	1.3	0.49
GDS-15	55	6.3	2.9	8.1	3.3	0.06
SRH	84	3.2	1.1	2.6	1.3	0.04
BMI	159	20.4	3.0	20.3	3.2	0.80
No. diagnoses	173	3.8	2.0	3.4	1.9	0.25
		n	%	n	%	$P^{\ddagger}$
Sex	Female	94	76.4	46	82.1	0.39
	Male	29	23.6	10	17.9	
Hearing impaired	No	95	77.9	32	57.1	0.005
	Yes	27	22.1	24	42.9	
Aphasia	No	116	94.3	50	89.3	0.23§
	Yes	7	5.7	6	10.7	
Diagnosis related to musculoskeletal systems	No	54	43.9	16	28.6	0.05
	Yes	69	56.1	40	71.4	
Diagnosis related to mental health	No	113	91.9	49	87.5	0.36
	Yes	10	8.1	7	12.5	
Diagnosis related to respiratory systems	No	90	73.2	49	87.5	0.03
	Yes	33	26.8	7	12.5	
Diagnosis related to neurological systems	No	21	17.1	10	17.9	0.90
	Yes	102	82.9	46	82.1	
Joint contracture	No	54	44.3	24	42.1	0.79
	Yes	68	55.7	33	57.9	
History of fracture	No	82	67.2	28	49.1	0.02
	Yes	40	32.8	29	50.9	
Limb paralysis	No	91	74.6	40	70.2	0.53
	Yes	31	25.4	17	29.8	
Arthritis	No	91	74.6	37	64.9	0.18
	Yes	31	25.4	20	35.1	
Osteoporosis	No	105	86.1	48	84.2	0.74
	Yes	17	13.9	9	15.8	
Hip prosthesis or open reduction	No	94	76.4	43	76.8	0.96
	Yes	29	23.6	13	23.2	
Cancer	No	106	86.9	52	91.2	0.40
	Yes	16	13.1	5	8.8	
Usage of medications or specific care for pain in the 6 h before the body movement protocol was carried out	No	118	97.5	52	94.5	0.37§
	Yes	3	2.5	3	5.5	

†The t-test; ‡χ^2-test; §Fisher's exact test. BMI, body mass index; GDS-15, Geriatric Depression Scale-15; MMSE, Folstein Mini-Mental State Examination; SRH, Self-Rated Health.

sociocultural variables that shape the individual's response to pain.[41] Previous studies also found that pain could trigger depression, and negatively impacts an individual's self-reported health status.[42,43] These findings suggest the presence of an important relationship among pain, health status and psychosocial conditions. Therefore, HCF care providers must carefully consider pain and its effects on residents' health status.

Table 3 Factors related to self-reported pain

	OR	95% CI Lower	Upper	*P*
SRH	0.50	0.28	0.88	0.016
Diagnosis related to mental health	9.18	1.27	66.52	0.028
Diagnosis related to respiratory systems	0.16	0.03	0.97	0.046

Multiple logistic regression analysis adjusting for age, numbers of diagnoses, hearing-impaired, aphasia and Global Deterioration Scale scores. Self-Rated Health (SRH) was entered as an ordinal variable, "bad" (1) to "excellent" (5). Odd ratio (OR) was calculated by an increment of the SRH level. CI, confidence interval.

Table 4 Statements about pain

	n	Agree		Disagree		Unknown	
		n	%	*n*	%	*n*	%
Pain should be tolerated.	73	50	68.5	12	16.4	11	15.1
Pain is a part of aging.	77	40	51.9	32	41.6	5	6.5
I always told staff when I suffer from pain.	73	20	27.4	42	57.5	11	15.1
I am hesitant to use analgesics because of fear of adverse effects	72	13	18.1	44	61.1	15	20.8

Table 5 Comparison between residents who reported pain and those who did not regarding their cognitive state and ability of daily livings

	Able to answer			Unable to answer			*P*
	n	Mean	SD	*n*	Mean	SD	
Cognitive state							
MMSE	147	14.4	8.8	58	0.9	2.6	<0.001
Global Deterioration Scale	179	4.8	1.4	67	6.5	0.5	<0.001
Ability of daily livings							
Barthel Index	179	41.3	28.0	67	10.0	16.7	<0.001

MMSE, Folstein Mini-Mental State Examination; SD, standard deviation.

Participating residents also reported that they tended to endure pain silently rather than report their pain to HCF staff, as reported previously by studies carried out in the Netherlands.[4,7] Furthermore, the residents who were not able to provide even one correct answer in an MMSE test (average score 0.9) would not have been able to report any experience of pain. The cognitive status of older residents and their beliefs about the connotations of reporting pain might exacerbate their condition. In these situations, care providers need to actively identify pain among residents. The pain management guidelines for aged care staff outline two approaches: active observation of patient behaviors that might indicate the experience of pain, and efforts to obtain reports from the patients themselves.[44] These approaches could help care providers to assess pain among older residents.

The present study had some limitations. Convenience sampling was used in the present study; just 33.4% of all residents participated. Therefore, the results of the present study might have limited generalizability. Residents who were admitted to a hospital and those who had serious health conditions were excluded. These residents were more likely to experience pain, which implies that our measure of prevalence might have been underestimated. The present study focused on pain occurring during body movement and the ability of an individual to report this experience of pain. Various other external and/or internal factors could affect an individual's self-reports of pain. Remarkably, 25% of residents were not able to report their pain; nearly 50% were unable to report their health or mental health conditions. Additional studies are required to further characterize this population.

The present study examined pain prevalence among 246 residents in nine HCF. Nearly half of the residents reported pain on movement. Self-rated health status and diagnoses related to mental health were significantly associated with the likelihood that a given resident would report an experience of pain. Residents should be encouraged to express how they are feeling to facilitate appropriate medical attention for pain management and long-term care.

Disclosure statement

No potential conflicts of interest were disclosed.

Acknowledgments

The authors are extremely grateful to all study participants, as well as the directors and staff of the participating facilities. This research was funded by Grants-in-Aid for Exploratory Research from the Ministry of Education, Culture, Sports, Science and Technology in Japan.

References

1 Akamine I, Masaki S. Tiiki zaijyu koureisya heno pein manejimento no dounyu [Introduction of pain management for the elderly community residents]. *J Okinawa Prefectual Coll Nurs* 2002; **3**: 25–31.
2 Kasai K, Tajita E. Zaitkukoureisya no syukantekikennkoukann to itami tono kankei [Association between the self-assessment of health status and pain in elderly people at home]. *J Nurs Soc Toyama Med Pharm Univ* 2001; **4**: 13–22.
3 Takai Y, Yamamoto-Mitani N, Chiba Y, Nishikawa Y, Sugai Y, Hayashi K. Prevalence of pain among residents in Japanese Nursing Homes: a descriptive study. *Pain Manag Nurs* 2011. doi: 10.1016/j.pmn.2011.01.005.
4 Boerlage AA, van Dijk M, Stronks DL, de Wit R, van der Rijt CC. Pain prevalence and characteristics in three Dutch residential homes. *Eur J Pain* 2008; **12**: 910–916.
5 Zanocchi M, Maero B, Nicola E *et al*. Chronic pain in a sample of nursing home residents: prevalence, characteristics, influence on quality of life (QoL). *Arch Gerontol Geriatr* 2007; **47**: 121–128.
6 Anzai S, Shiba Y, Haga H. Chiikizaijyukoureisyano undoukinou teikani kanrensuru sintaino itami [Association between physical function and musculoskeletal pain in community-dwelling elderly people]. *Nippon Ronen Igakkai Zasshi* 2012; **49**: 234–240.
7 van Herk R, Boerlage AA, van Dijk M, Baar FP, Tibboel D, de Wit R. Pain management in Dutch nursing homes leaves much to be desired. *Pain Manag Nurs* 2009; **10**: 32–39.
8 Takai Y, Yamamoto-Mitani N, Okamoto Y, Koyama K, Honda A. Literature review of pain prevalence among older residents of nursing homes. *Pain Manag Nurs* 2010; **11**: 209–223.
9 Torvik K, Kaasa S. Kirkevold Ø, Rustøen T. Pain in patients living in Norwegian nursing homes. *Palliat Med* 2009; **23**: 8–16.
10 Zwakhalen S, Koopmans R, Geels P, Berger M, Hamers J. The prevalence of pain in nursing home residents with dementia measured using an observational pain scale. *Eur J Pain* 2009; **13**: 89–93.
11 Ministry of Health Labour and Welfare. Heisei 19 nen Kaigo sa-bisu sisetu/jyugyousyo tyousa kekka no jyoukyou [Survey about care service facilitis in 2007]. [serial on the Internet]. [Cited 1 Dec 2012]; 2011(January 4)}: [about 1 p.]. Available from URL: http://www.mhlw.go.jp/toukei/saikin/hw/kaigo/service07/index.html.
12 Gibson SJ, Scherer SC, Goucke CR. Australian Pain Society and the Australian Pain Relief Association Pain Management Guidelines for Residential Care, Stage 1 Preliminary field-testing and preparations for implementation. 2004.
13 Takashima R, Murata W. How users of a Long Term Care Health Facility who have a walking disability feel about walking. *Hokkaido J Occup Ther Hokkaido Sagyo Ryoho* 2012; **29**: 25–32.
14 Takai Y, Yamamoto-Mitani N, Fukahori H, Kobayashi S, Chiba Y. Nursing ward managers' perceptopns of pain prevalence at the aged-care facilities in Japan: a nationwide survey. *Pain Manag Nurs* 2011; doi: 10.1016/j.pmn.2011.04.004.
15 Proctor W, Hirdes J. Pain and cognitive status among nursing home residents in Canada. *Pain Res Manag* 2001; **6**: 119–125.
16 Yasar E, Vural D, Safaz I *et al*. Which treatment approach is better for hemiplegic shoulder pain in stroke patients: intra-articular steroid or suprascapular nerve block? A randomized controlled trial. *Clin Rehabil* 2011; **25**: 60–68.
17 Wagner LM, Clevenger C. Contractures in nursing home residents. *J Am Med Dir Assoc* 2010; **11**: 94–99.
18 Mahoney F, Barthel D. Functional evaluation: the barthel index. *Md State Med J* 1965; **14**: 61–65.
19 Hachisuka K, Okazaki T, Ogata H. Self-rating Barthel index compatible with the original Barthel index and the Functional Independence Measure motor score. *J Univ Occup Environ Health* 1997; **19**: 107–121.
20 Folstein M, Folstein S, McHugh P. "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res* 1975; **12**: 189–198.
21 McDowell I. *Measuring Health: A Guide to Rating Scales and Questionnaires*, 3rd edn. Oxford: Oxford University Press, 2006.
22 Reisberg B, Ferris SH, Deleon MJ, Crook T. The global deterioration scale for assessment of primary degenerative dementia. *Am J Psychiatry* 1982; **139**: 1136–1139.
23 Mimori Y, Ohshita T, Shirai T. Global Deterioration Scale (GDS). *Nippon Rinsho* 2003; **61**: 137–140.
24 Reisberg B, Sclan SG, Franssen E, Kluger A, Ferris S. Dementia staging in chronic care populations. *Alzheimer Dis Assoc Disord* 1994; **8** (Suppl 1): S188–S205.
25 Kurlowicz L. The Geriatric Depression Scale. Best Practices in Nursing Care to Older Adults. [serial on the Internet]. [Cited 1 Apr 2009.]: [about 1 p.]. Available from URL: http://www.nursingcenter.com/prodev/ce_article.asp?tid=742420.

26 McGivney SA, Mulvihill M, Taylor B. Validating the GDS depression screen in the nursing home. *J Am Geriatr Soc* 1994; **42**: 490–492.
27 Mossey JM, Shapiro E. Self-rated health: a predictor of mortality among the elderly. *Am J Public Health* 1982; **72**: 800–808.
28 Bombak AE, Bruce SG. Self-rated health and ethnicity: focus on indigenous populations. *Int J Circumpolar Health* 2012; **71**: 18538.
29 Cimolin V, Vismara L, Galli M, Zaina F, Negrini S, Capodaglio P. Effects of obesity and chronic low back pain on gait. *J Neuroengineering Rehabil* 2011; **8**: 55.
30 Herr K, Spratt KF, Garand L, Li L. Evaluation of the Iowa Pain Thermometer and older selected pain intensity scales in younger and older adults cohorts using controlled clinical pain. *Pain Med* 2007; **8**: 585–600.
31 Herr K, Spratt K, Mobily P, Richardson G. Pain intensity assessment in older adults: use of experimental pain to compare psychometric properties and usability of selected pain scales with younger adults. *Clin J Pain* 2004; **20**: 207–219.
32 Takai Y, Yamamoto-Mitani N, Chiba Y, Nishikawa Y, Hayashi K, Sugai Y. Abbey Pain Scale: development and validation of the Japanese version. *Geriatr Gerontol Int* 2010; **10**: 145–153.
33 Takai Y, Yamamoto-Mitani N, Chiba Y, Kato A. Feasibility and clinical utility of the Japanese version of the Abbey Pain Scale in Japanese aged care. *Pain Manag Nurs* 2012. doi: 10.1016/j.pmn.2012.02.003.
34 Abbey J, Piller N, De Bellis A *et al*. The Abbey pain scale: a 1-minute numerical indicator for people with end-stage dementia. *Int J Palliat Nurs* 2004; **10**: 6–13.
35 Ramont RP, Niedringhaus DM, Towle MA. *Comprehensive Nursing Care*, 2nd edn. Upper Saddle River, NJ: Pearson, 2010.
36 Leininger MM, McFarland MR. *Transcultural Nursing: Concepts, Theories, Research and Practice*, 3rd edn. New York: McGraw-Hill, Medical Pub. Division, 2002.
37 Gibson M, Woodbury M, Hay K, Bol N. Pain reports by older adults in long-term care: a pilot study of changes over time. *Pain Res Manag* 2005; **10**: 159–164.
38 Achterberg W, Pot A, Scherder E, Ribbe M. Pain in the nursing home: assessment and treatment on different types of care wards. *J Pain Symptom Manage* 2007; **34**: 480–487.
39 Lukas A, Mayer B, Fialova D *et al*. Pain characteristics and pain control in European nursing homes: cross-sectional and longitudinal results from the services and health for elderly in long TERm care (SHELTER) study. *J Am Med Dir Assoc* 2013; doi: 10.1016/j.jamda.2012.12.010.
40 Dysvik E, Lindstrom TC, Eikeland OJ, Natvig GK. Health-related quality of life and pain beliefs among people suffering from chronic pain. *Pain Manag Nurs* 2004; **5**: 66–74.
41 Fishman S, Ballantyne J, Rathmell JP, Bonica JJ. *Bonica's Management of Pain*, 4th edn. Baltimore, MD: Lippincott, Williams & Wilkins, 2010.
42 Sukegawa T, Itoga M, Seno H *et al*. Sleep disturbances and depression in the elderly in Japan. *Psychiatry Clin Neurosci* 2003; **57**: 265–270.
43 Smalbrugge M, Jongenelis LK, Pot AM, Beekman AT, Eefsting JA. Pain among nursing home patients in the Netherlands: prevalence, course, clinical correlates, recognition and analgesic treatment – an observational cohort study. *BMC Geriatr* 2007; **7**: 3.
44 Edith Cowan University. *The PMG Kit for Aged Care: An Implementation Kit for The Australian Pain Society's Pain in Residential Aged Care Facilities Manegement Strategies*. Barton: ACT Commonwealth of Australia, 2007.

V. 資　料

参　考　資　料

職場における腰痛の効果的な治療法等に関する研究

研究代表者　松平浩　東京大学医学部附属病院 22 世紀医療センター
運動器疼痛メディカルリサーチ＆マネジメント講座