資料 19：
EAFONS 学会発表資料

The Relationship Between the Frequency of Tasks and Acute and Chronic Low Back Pain Among Nurses
A Cross-Sectional Study

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Low Back Pain (LBP) Among Nurses

72.9% (2012) (Yamanaka, 2015)

- Heavy physical workload
- Lift-ing and moving patients
- Adverse postures

(Smedley, Egger, Cooper, & Coggon, 1997)

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Acute LBP & Chronic LBP

Based on research,

LBP was divided into two main groups

1. Acute LBP : <3 months
2. Chronic LBP : ≥3 months

Chronic LBP is related to sick leave, change of work or work tasks. (Eriksen, 2003)

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Aim

1. To investigate the prevalence of chronic LBP among nurses.

2. To investigate the associations between the frequency of nurses' tasks and the acute LBP / chronic LBP.

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Methods

■ Participants
1,100 nurses from a national university hospital

■ Design
Cross-sectional study
By self-administered questionnaire

■ Ethics
This research approved by Kyoto University Hospital Ethics Committee (R0131)

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Questionnaire

1. Demography
- age
- gender
- nursing career
- shift
- depressive (CES-D)

2. Experience of LBP over the past year
- acute LBP / chronic LBP
- diagnoses
- degree of pain (Numeric Rating Scale)

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Questionnaire (continued)

3. Frequency of nurses' tasks

"Do you frequently … ?"

- reposition patients in bed
- treat patients on the bed
- transfer patients between the bed and the stretcher
- transfer patients between the bed and the wheelchair
- assist patients to sit in bed
- assist patients to stand up
- assist patients to take a bath

4. Devices & Equipment

- adjusted the height of the bed
- instruments

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Statistical analysis

- We fit a generalized logit model to examine the association between the frequency of nurses' tasks and the acute LBP / chronic LBP
- Data was analyzed using JMP® pro 11.2.0
- Statistical significance was set at the $p>0.05$ level, two-tailed.

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Results

Effective respondents
799 (72.6%)

Nurses respondents
758 (69.0%)

(41 nurse aids were excluded)

		n	(%)
Gender	male	72	(9.5)
	female	678	(89.4)
	missing	8	(1.1)
Nursing career			
	1y	76	(10.0)
	2-5y	237	(31.3)
	6-10y	148	(19.5)
	11-20y	194	(25.6)
	21y<	99	(13.1)
	missing	4	(0.5)
Depressive symptom			
	no	460	(60.7)
	yes	296	(39.1)
	missing	2	(0.3)

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The prevalence of LBP Classified

N=758

	n (%)	
Without LBP	272	(35.9)
Acute LBP	357	(47.1)
Chronic LBP	129	(17.0)

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Relationship Demographic and LBP

		Without LBP (n=272)		Acute LBP (n=357)		Chronic LBP (n=129)		
		n	%	n	%	n	%	p値[a]
Gender	Male	21	(7.7)	38	(10.6)	13	(10.1)	0.4256
	Female	250	(91.9)	314	(88.0)	114	(88.4)	
	Missing	1	(0.4)	5	(1.4)	2	(1.6)	
Nursing career	1y	48	(17.6)	20	(5.6)	8	(6.2)	0.0011
	2-5y	89	(32.7)	118	(33.1)	30	(23.3)	
	6-10y	52	(19.1)	66	(18.5)	30	(23.3)	
	11-20y	57	(21.0)	99	(27.7)	38	(29.5)	
	21y<	24	(8.8)	52	(14.6)	23	(17.8)	
	Missing	2	(0.7)	2	(0.6)	0	(0.0)	
Depressive	Yes	95	(34.9)	136	(38.1)	65	(50.4)	0.0112
	No	177	(65.1)	219	(61.3)	64	(49.6)	
	Missing	0	(0.0)	2	(0.6)	0	(0.0)	

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Estimating LBP by generalized logit model

	Acute LBP		Chronic LBP	
	Crude		Crude	
	OR	95% CI	OR	95% CI
Transferring between bed and wheelchair	1.24	1.05-1.47	1.24	0.99-1.54
Assisting to sit in bed	1.31	1.10-1.56	1.28	1.02-1.60
Assisting from bed to standing	1.23	1.04-1.47	1.24	0.99-1.56
Assisting to take a bath	1.04	0.82-1.32	1.15	0.84-1.54
Treating on the bed	1.10	0.90-1.35	1.04	0.80-1.37
Repositioning in bed	1.25	1.06-1.46	1.10	0.89-1.36
Transferring between bed to stretcher	1.01	0.85-1.21	0.98	0.77-1.23

The association is expressed as Odds Ratio (OR) with 95% Confidence Interval (95% CI)

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Estimating LBP by generalized logit model (adjusted for length of the nursing career, and depression)

	Acute LBP		Chronic LBP	
	Adjusted		Adjusted	
	OR	95% CI	OR	95% CI
Transferring between bed and wheelchair	1.32	1.10-1.58	1.36	1.08-1.71
Assisting to sit in bed	1.36	1.13-1.63	1.35	1.07-1.71
Assisting from bed to standing	1.28	1.07-1.54	1.32	1.04-1.67
Assisting to take a bath	1.10	0.86-1.42	1.23	0.89-1.68
Treating on the bed	1.24	1.00-1.54	1.20	0.91-1.60
Repositioning in bed	1.30	1.10-1.54	1.16	0.92-1.45
Transferring between bed to stretcher	1.03	0.86-1.24	0.98	0.76-1.24

The association is expressed as Odds Ratio (OR) with 95% Confidence Interval (95% CI)

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Devices & Equipment

Instruments		Existence, n(%)		Usage, n (%)	
Sliding board (for bed)		662	(87.3)	548	(72.3)
Sliding sheet		455	(60.0)	197	(26.0)
Wheelchair detachable		376	(49.6)	149	(19.7)
Sliding board (for chair)		237	(31.3)	52	(6.9)
Lifting machine (on hover matt)		54	(7.1)	8	(1.1)
Nothing		47	(6.2)	116	(15.3)

multiple answer, N=758

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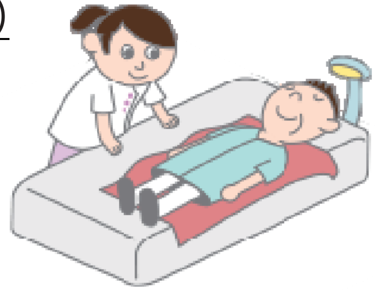
Devices & Equipment

Adjusted the height of bed

	n	(%)
always	124	(16.4)
usually	315	(41.6)
rare	230	(30.3)
no	47	(6.2)
missing	42	(5.5)



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Discussion

Prevalence of chronic LBP

Nurses 17.0%

Workers <6% (Matsudaira, 2009)

Elderly care workers 10.1% (Iwakiri, 2016)

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The frequency of tasks and LBP

Acute LBP → **Chronic LBP**

Acute LBP:

- Transfer between the bed and the wheelchair
- Assist to sit in bed
- Assist to stand up

Chronic LBP:

- Transfer between the bed and the wheelchair
- Assist to sit in bed
- Assist to stand up

Acute LBP:

- Reposition in bed
- Treat on the bed

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The frequency of tasks and LBP

Acute LBP → **Chronic LBP**

Usage of devices and equipment

By using the appropriate devices and equipment, acute LBP might not develop chronic LBP

Always + Usually	58.0%
Rare + No	36.5%

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Conclusion

- Chronic LBP 17.0%
- Patient handling without devices and equipment were associated with chronic LBP
- Proactive use of devices prevents chronicity of LBP, and habitual use of equipment prevents LBP

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Acknowledge

This work was supported by Health Labor Sciences Research Grant

Thank you for your attention

京都大学
KYOTO UNIVERSITY

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資料 20：

医療の質・安全学会学術集会発表資料

てんかん患者の転倒予防に対するリフト使用
～ビデオ脳波モニタリング検査における取組み～

第11回医療の質・安全学会学術集会

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2016年11月19日

第11回医療の質・安全学会学術集会 COＩ開示

筆頭発表者名：　和田山智子

演題発表に関連し、開示すべきCOＩ関係にある企業などはありません。

Contents

Ⅰ, てんかん患者をとりまく環境 社会的問題

100万人（100人に1人）

誤解や偏見（けいれんし倒れる）
＊てんかん患者の自動車事故
＊就労困難や解雇

↓

社会参加の制限
適切な診断・治療が重要

Ⅰ，てんかん患者をとりまく環境
検査・診断・治療

問診（発作時の状態）

↓

身体的診察（麻痺がないかなど）

↓

脳波：数時間・24時間:長時間ビデオ脳波モニタリング検査（VEEG）

MRI(CT)・SPECT検査・血液検査・心理検査・髄液検査

↓

正しい診断

↓

正しい治療：内科的治療・外科的治療

全国で47施設
2012年調査
（大槻泰介　他． 2013）

Ⅰ，てんかん患者をとりまく環境：検査
長時間脳波モニタリング（VEEG）①

- 検査中に、薬剤の減量または休薬することでてんかん発作が起こりやすくする
- 24時間脳波を装着し、24時間ビデオカメラにて継続的にてんかん発作の状態を観察することで、診断に重要な役割を果たす
- 脳のどの部分から発作が始まり、どのように拡がっていくかということが確認できる
- 手術適応であれば、発作部位の焦点除去手術を行うことが出来、根治的治療につながる

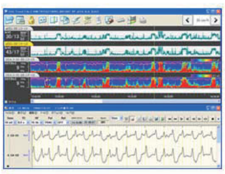
Ⅰ，てんかん患者をとりまく環境：検査

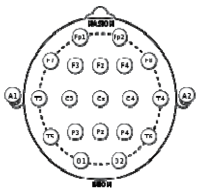
長時間脳波モニタリング（VEEG）②

A病院でのEpilepsy Monitoring Unit(EMU)の変遷

VEEG：40-50例/年
1例につき：1-2週間のEMUでの検査

侵襲的ビデオ脳波モニタリング検査：4-8例/年
（外科手術を伴う）





1991　EMU開設
1992　てんかん手術初例
2000　VEEG開始　1室
2008　VEEG開始　2室

Ⅱ，VEEG検査中の事故

有害事象	数（%）
転倒・転落	48 (68.6)
てんかん発作重責状態	44 (62.9)
発作後精神病	38 (54.3)
埋め込みリードの事故抜去	22 (39.8)
裂傷	15 (21.4)
肺炎	7 (10)
心停止	5 (7.1)
骨折	4 (5.7)
脳震盪（転倒による）	3 (4.3)
死亡	2 (2.9)

(SHAFER, PO., et al, 2011)

Ⅱ，VEEG検査中の事故
てんかん患者の転倒場所の傾向

	EMUの患者	他の神経内科入院患者
病室	26%	68%
トイレ	74%	24%

(Pati Sandipan, et al, 2013)

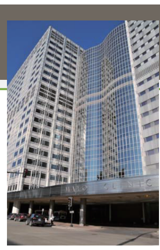
EMU（A病院）の転倒および外傷状況：5件
（1991-2014：2014-2015に2件）

Ⅲ, A病院のVEEG
これまでの転倒（外傷）予防対策

- 原則Bed上安静
- 洗面・トイレ歩行時は、看護師付添
- トイレは、原則身障者用トイレ、トイレ内も看護師付添
- 夜間　Bed　4点柵
- 常時Bed柵カバー設置

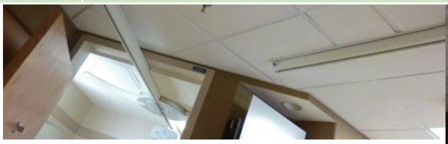
予防対策のリスクと限界

➢発作型によっては、転倒防止が困難
⇒骨折や頭部外傷のリスクがある
➢看護師の障害
⇒患者保護のための行動が、
看護師の外傷につながる



2014年3月
Mayo Clinic in Rochester, USAへ見学

2014年4月	診療科医師へEMUの安全対策「天井走行リフト活用」報告
2015年4~8月	診療科医師・看護部・建築掛など協働 EMUの天井 走行式リフトの設置案の検討と決定



Ⅳ, A病院のVEEG中のリフトを使用した転倒予防対策の取り

医療スタッフ

- 看護師用マニュアル作成
- 看護師の発作時対応訓練
- 医師と共に患者説明

2016年1月12日	EMUでの天

24時間ビデオ脳波モニタリング検査を受けられる患者さん･ご家族へ

～リフト使用のご案内～

24時間ビデオ脳波モニタリング検査では、薬を減らし発作が起こりやすい状態にすることがあります。
このためトイレや洗面などで歩行の際は、発作による転倒やけがの危険性が高くなります。
24時間ビデオ脳波モニタリング検査を実施中は、室内移動時にリフトの使用を推奨しています。
発作の型によっては、必ず装着をお願いする場合もございますのでご了承ください。

リフト装着時の状態です
万が一歩行時に発作がおこれば、緑色の装具（スリング）部分とリフト本体で身体が倒れるのを

リフトを操作するリモコンです。
トイレの際に患者さん自らリフトを操作していただくことが可能です。

股部分のベルトを使用しない場合はこのようになります。
大発作が起きない場合はこのように装着することもあります。

股部分のベルトを使用する場合はこのようになります。
大発作の危険性が高い場合はこのようにベルトを使用します。

Ⅳ,　A病院のVEEG中のリフトを使用した転倒予防対策の効果

11名のEMU入院
（2016年1月～2016年3月末）

- 全患者にリフト使用を勧めた
- 4名の同意を得、リフト使用ができた
- 1名の転倒をふせぐことができた

トイレ歩行中に発作を認め意識消失に至ったが、
リフトが支えとなった

Ⅴ, 考察・課題

- USAにおける報告
  リフト使用を開始した2013年末から
  15か月間にEMUでの転倒事例が0件
- 転倒による外傷ゼロへの可能性
- リフト使用の患者理解を得ることが困難

まとめ

- てんかん患者の適切な診断・治療は、患者のQOLにおいて重要
- 検査中の事故防止は必須
- リフト使用によりVEEG中の転倒を予防できる

文献

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資料 21：
医療の質・安全学会学術集会発表資料

ノーリフト（持ち上げない看護）で生まれる2つの効果

～器具を使うとケアの質が向上する～

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3.京都大学大学院医学研究科人間健康科学系専攻
4.名古屋大学医学部附属病院医療の質・安全管理部

第11回医療の質・安全学会学術集会 COＩ開示

筆頭発表者名：　山中　寛恵

演題発表に関連し、開示すべきCOＩ関係にある企業などはありません。

背景と目的

- □ 人力のみによる患者の移動介助行為によって患者と職員の安全が損なわれている
- □ 人力のみに頼らない、患者の安全な移動介助(ノーリフト)を推進するためのシステムを構築する

2009年　A大学病院調査　n=805

図1-1 過去一年間の腰痛

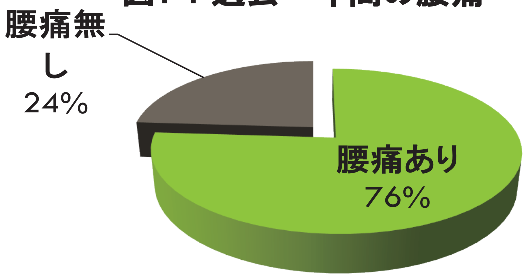
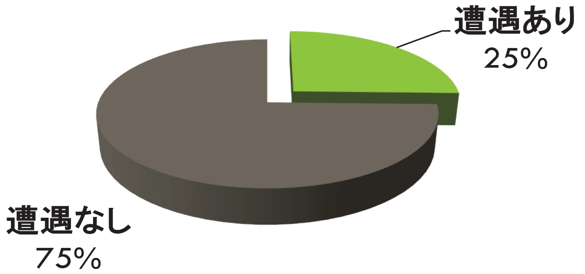


図1-2　移動介助時の患者の事故



実践内容

- □ ノーリフトを実践するためのシステムを構築する

【ノーリフト指針】
- ・人力のみによる患者の移乗・移動を避ける
- ・環境の整備
- ・移乗介助器具(以下器具)の選定と患者のアセスメント
- ・器具使用についての教育とトレーニング
- ・器具の管理
- ・管理者および個人の責任　等

- □ 腰痛および器具の使用に関する質問紙調査を実施する
- □ 重症度、医療・看護必要度評価において、寝返り、移乗に介助を要する患者を母数として器具使用比を調査する

結果1：ノーリフト実践の環境を整備する

表1　移乗介助器具配置数　2016/10/31現在

介助器具の種類	配置数
天井走行リフト	4台
床走行リフト	5台
スライディングボード	96枚
スライディングシート	316枚

表2　ノーリフト院内認定者数　2016/10/31現在

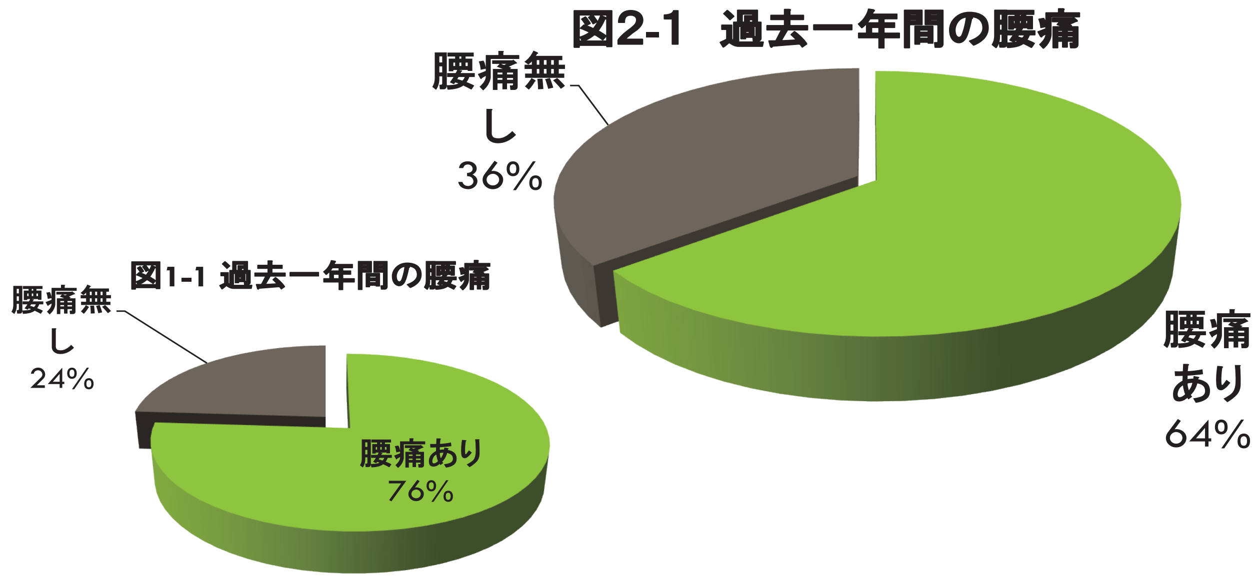
認定レベル	習得目標	認定者数
Ⅰ	スライディングシート・ボードを用いた水平移動技術	97名
Ⅱ	端坐位介助の技術	16名
Ⅲ	リフトを用いた移動技術	13名

結果2：腰痛および器具使用に関する調査

- □ 調査期間：2015年7月14日～30日
- □ 調査対象：A大学病院に勤務する看護職員
- □ 対象者数：1,200
- □ 回答者数：915(76.2%)
- □ 有効回答者数：807
- □ 主な質問項目
  - ・急性・慢性腰痛の発生および診断について
  - ・腰部への負担を感じる動作について
  - ・移動介助器具の使用状況
  - ・移動介助時の人手の要請状況
  - ・移動介助の　患者の事故　等

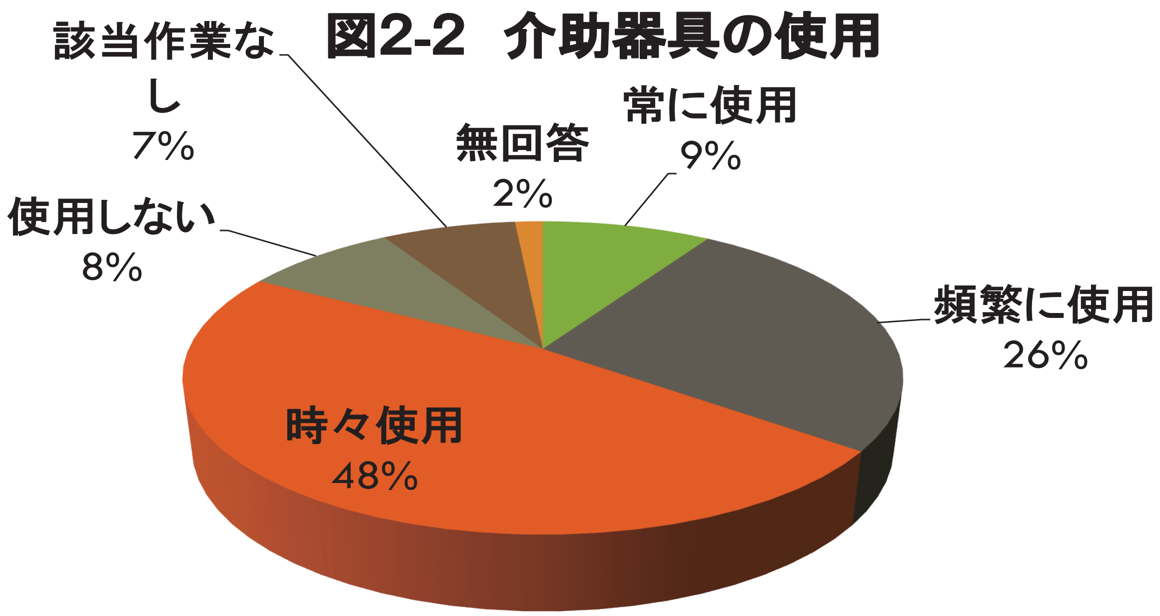
看護職員の腰痛発生と器具の使用状況

2015年　A大学病院調査　n=807



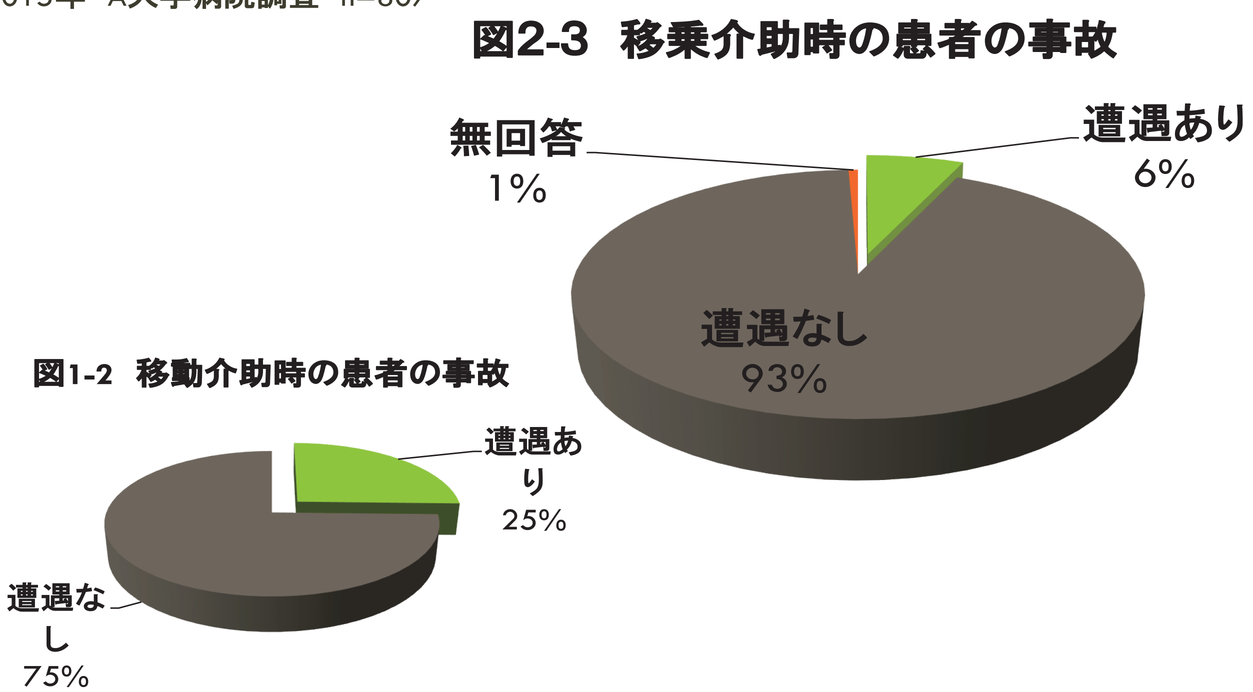
看護職員の腰痛発生と器具の使用状況

2015年　A大学病院調査　n=807

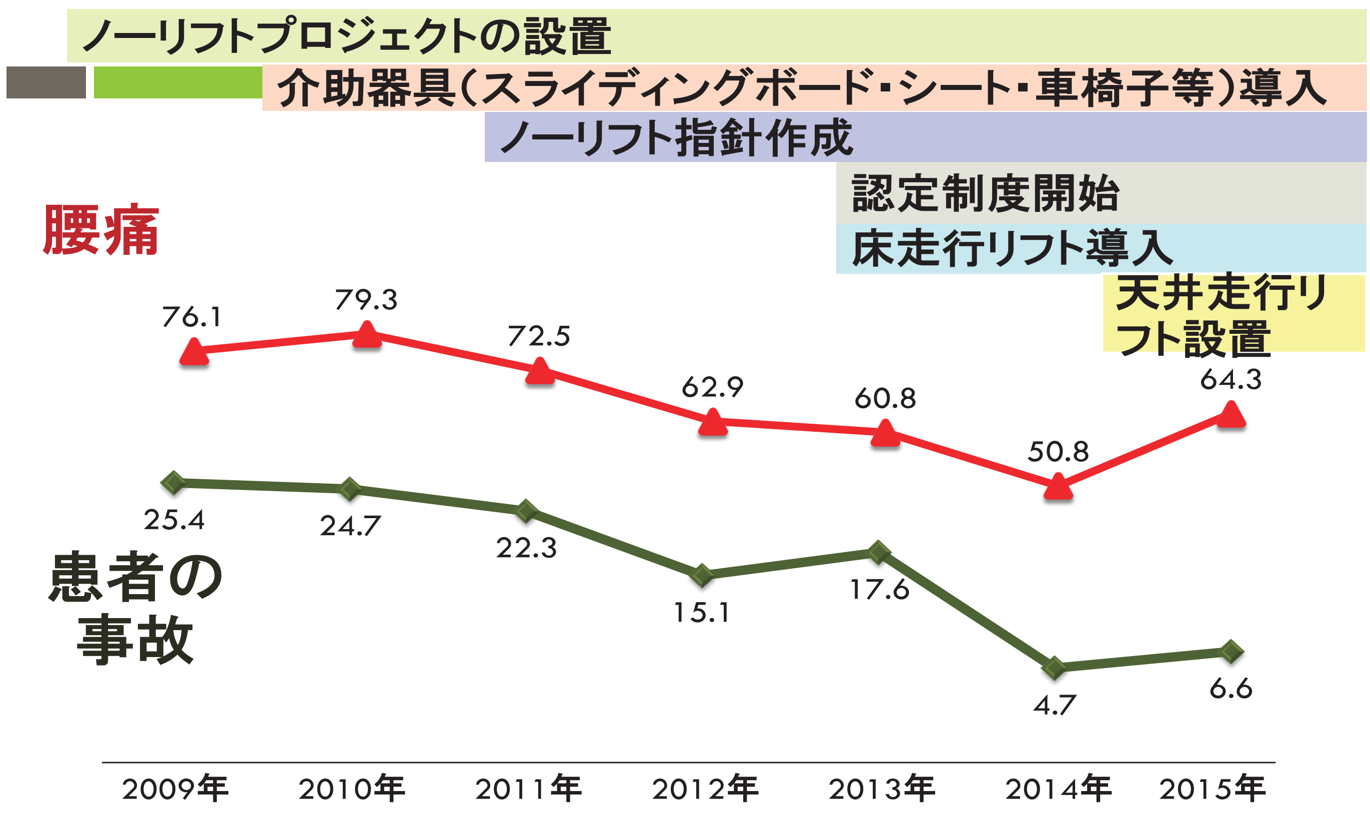


看護職員の腰痛発生と器具の使用状況

2015年　A大学病院調査　n=807



腰痛発生率と事故発生率の推移



結果3：移動介助器具使用比

- 重症度、医療・看護必要度評価を用いて、移動介助器具の使用状況を調査

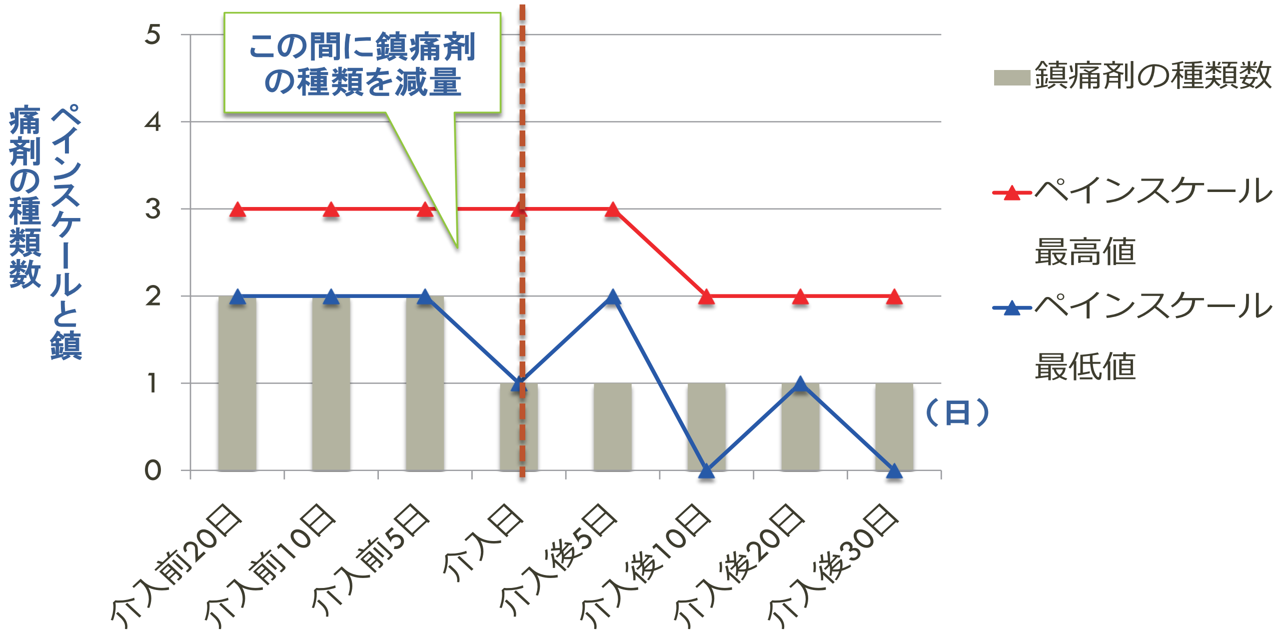
※器具使用比＝ 器具を使用している患者数 / 必要度B項目の寝返り、移乗介助を必要とする患者数

事例紹介

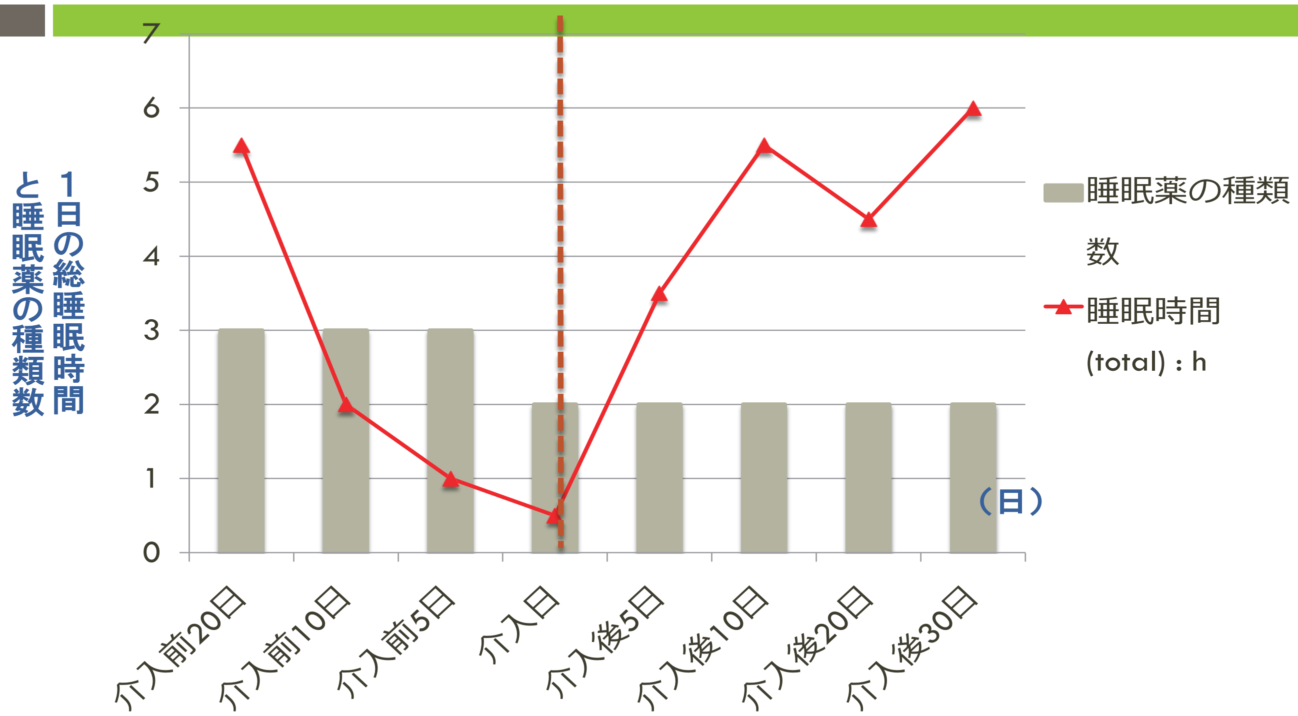
- 60歳代，脳幹部海綿状血管腫摘出術後，意識清明
- 脳幹部の障害：四肢麻痺（徒手筋力テスト0−1/5）
- 基本動作：全介助（ 機能的自立度評価表:26点）
- 下肢感覚：神経障害痛、表在,深部感覚重度鈍麻（ペインスケール2—4/5
  鎮痛剤3剤を使用）
- 不眠が続き、昼夜問わず様々な訴えあり

リフト、HALを使用し離床を図る

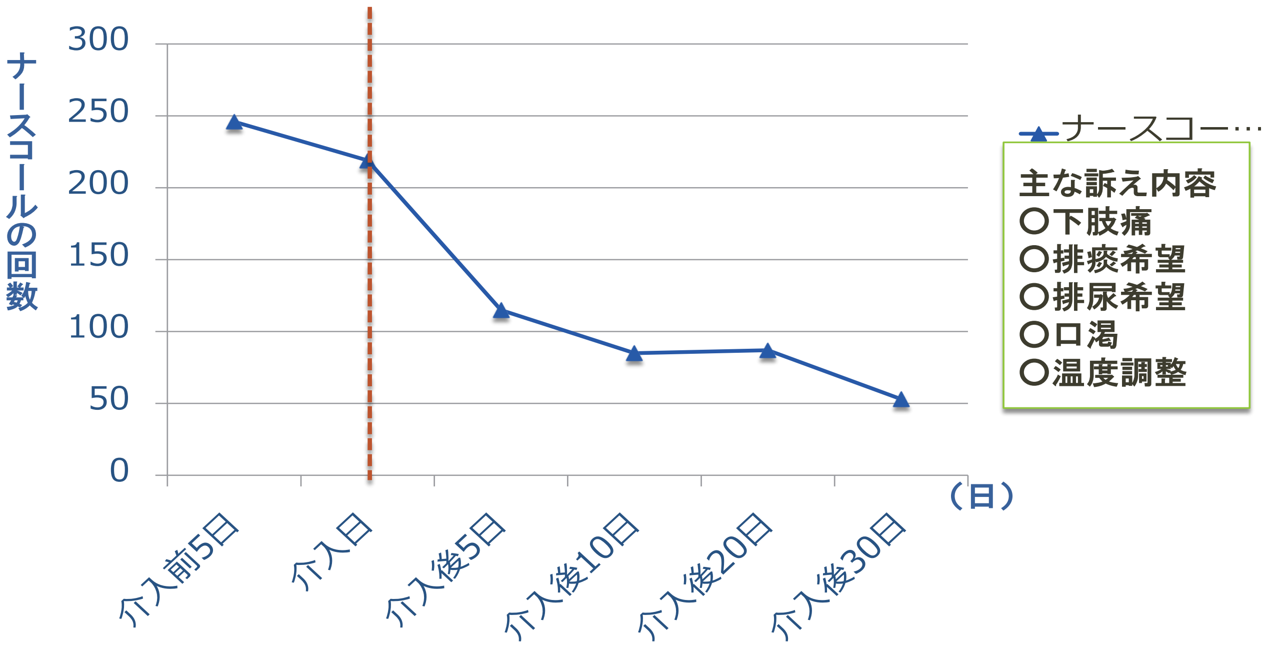
下肢痛が改善



睡眠が改善

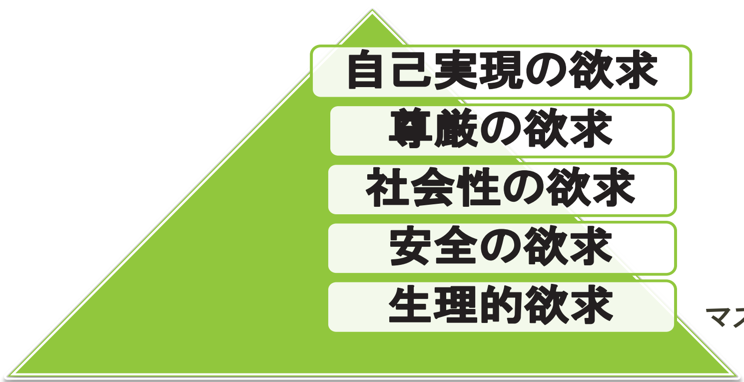


Nsコールによる訴えの回数が減少



結果4：器具の使用によるケアの質向上

- □ 転倒リスクの高い患者の転倒を予防することができた
- □ 褥瘡がある患者の体位変換時の苦痛が軽減した
- □ 立位保持ができなくてもトイレで排泄ができた
- □ リフトの使用により病棟内リハビリテーションが向上した
- □ 患者自身の活動範囲が拡大した



マズローの欲求5段階説

考按

- □ ノーリフト活動によって、移乗時の患者の事故および看護職員の腰痛が減少した。
- □ 人力のみでは限界があった患者のニーズの充足が可能になった。
- □ 移乗・移動介助時に器具を使用する頻度は、20%以下であった。
- □ ノーリフト活動の推進には、器具を使用する環境の整備、教育およびピアリーダーの育成が求められる。

結語

- □ ノーリフトは、患者安全および看護職員の労働安全にとって有用である。
- □ ノーリフトによって、ケアの際の患者の苦痛が緩和されると共に、これまで困難であった患者のニーズ充足が可能になった。
- □ ノーリフトの推進には、環境整備、教育およびピアリーダーの育成が求められる。

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ご清聴ありがとうございました。

資料 22：

International Congress on Spinal Pain.

Presentation Code: P2-49

Validation of the spine kinematics using the gyroscope

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INTRODUCTION

The spinal kinematic analysis accomplished evolution from a body surface evaluation to in-vivo three-dimensional kinematic analysis. So an unknown thing becomes known and a known evidence is changed. However, the spinal pain occurs in scene the everyday life, not at laboratory. Therefore we focus on to the gyroscope which was available for measurement easily in an everyday life scene. The purpose of this study is a reliability test of the kinematic analysis of the trunk using the gyroscope. We assumed the angle obtained from the 3D motion capture device a correct angle level.

METHODS

Subjects are normal male eight people. We put on a triaxiality accelerometer, triaxiality angular velocity meter for C7 and L3 of subjects (Fig. 1). Subjects were standing, task1; touch it with both hands at both knees, task2; touch the right knee with your right hand the trunk succumbed side, task 3; Please touch the left knee with the right hand (Fig. 2).

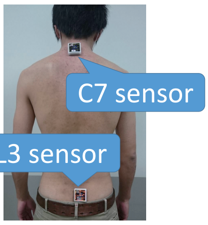

Fig. 1

task 1 task 2 task 3

Fig. 2

RESULTS

Each ICC of the angle obtained from the sensor and the 3D motion capture device were 0.89 (sagittal plane: Fig. 3), 0.70 (frontal plane: Fig. 4), 0.72 (horizontal plane: Fig. 5). ICC was the highest in task1 in the working and withdrew in order of task2, task3.

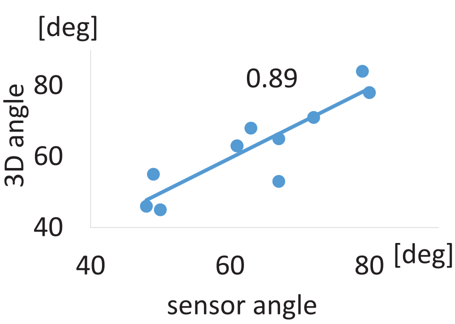

Fig. 3 task 1 sagittal angle

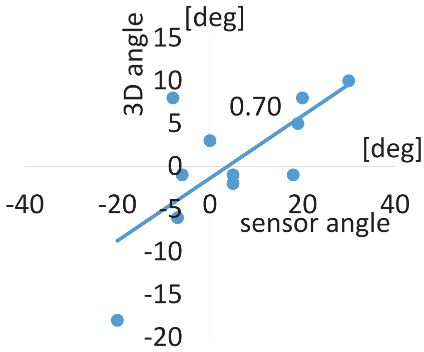

Fig. 4 task 1 frontal

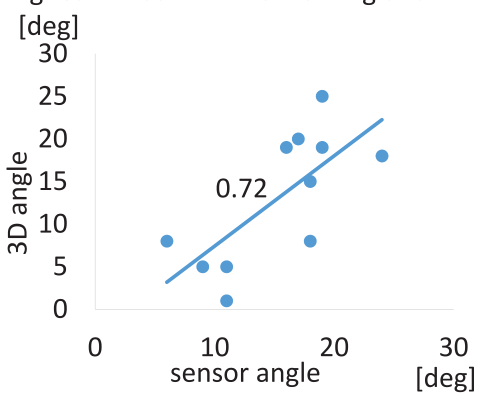

Fig. 5 task 1 horizontal

CONCLUSIONS

We integrate it to measure an angle using an angular velocity sensor. In doing so, the error for the constant of integration will occur. If a displacement angle becomes big, we can ignore this error, but an error seems to grow big when a displacement angle catches small rotation. It was not found whether this had a clinically major meaning in this study.

THE 1ST INTERNATIONAL CONGRESS ON SPINAL PAIN

資料 23：

ICMMA 発表資料

Analysis of Trunk Movement for Pregnant Women with Lumbopelvic Pain Using Inertial Measurement Unit

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ABSTRACT

Many women experience lumbopelvic pain (LPP) during pregnancy. It is thought that motion patterns, especially when accompanied by flexure and rotation of the trunk, are associated with LPP. This study investigates methods to evaluate the characteristics of the motion patterns that affect LPP during pregnancy. An experiment was conducted to obtain the motion characteristics of standing up and sitting down of pregnant women by using an inertial measurement unit (IMU). Then motion evaluation indexes were proposed from measured data of lumbar angular velocity obtained from the IMU. Next, the proposed indexes, maximum peak value, minimum peak value, peak-to-peak (PP: range between maximum and minimum peaks) value, time of PP, PP divided by time of PP, root mean square of each parameter, and each index divided by body mass index (BMI), were calculated during standing up and sitting down for the roll, pitch, and yaw angles. Finally, we considered the presence of any relation between LPP and the motion characteristics by comparing the proposed indexes of an LPP group with those of a non-LPP group. Thus, it appears that maximum peak, PP/time of PP, maximum peak/BMI, PP/BMI, and (PP/Time of PP)/BMI of the pitch angle have some relevance to LPP.

CCS Concepts

• **Information systems→Mobile information processing systems**

ICCMA '16, December 07-11, 2016, Barcelona, Spain

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Keywords

Human motion analysis; Lumbopelvic pain;Pregnant women.

1. INTRODUCTION

Lumbopelvic pain (LPP), such as lower back and pelvic girdle pain, is a common discomfort during pregnancy [1,2]. The symptom lowers the quality of life for many women during and after pregnancy [3-5]. Therefore, the treatment of LPP is needed to facilitate a comfortable pregnancy. However, there are limitations to the treatments available for pregnancyowing to their adverse effects on women and the developing fetuses [6,7]. The main factors related to LPP in pregnancy are thought to be elasticity of the joint due to pregnancy-related hormones and weight gain [8,9]; however, these factorsareessential for pregnancy. Unfortunately, they generate excessive physical stress for women during some activities, and result in LPP. The motions that include flex rotation of the trunk, such as sitting/standing and bending, are especially thought to be related to LPP [10,11]. These activities can be evaluated and corrected using a method that causes little adverse influence on pregnancy, and includes exercise and instructions based on motion patterns [12,13].Therefore, the motion characteristics that cause physical stress should be investigated for LPP management during pregnancy.

Regarding motion analysis in clinical practice, therapists usually conduct an objective assessment by observation; thus, low reliability is a problem. In contrast, the inertial measurement unit (IMU) enables us to measure some motion objectively. Moreover, it does not disturb the person’s motion or restrict the measurement environment, because it is a small and lightweight device. Thus, it has been frequently used to analyze gait in a straight path [14,15]. However, motion analysis that includes flexure and rotation of the trunk is generally conducted by a three-dimensional motion analysis system [16,17]. A few studies that analyze sit-to-stand movement using an IMU have been conducted [18].

Therefore, considering the merits of the IMU, this study aims to conduct motion analysis of sitting down and standingup for pregnant women and investigate the influence of motion patterns on LPP, based on the results of IMU motion analysis. To achieve this purpose, we devised the methods for identification of the phrase of motion of sitting down and standing up. Evaluation indexes for sitting down and standing up were proposedfrom measured data of lumbar angular velocity. Lastly, we considered whether there is any relation between LPP and the motion characteristics by comparing the proposed motion evaluation indexes of LPP and non-LPP participant groups.

2. BODYMOTION ANALYSIS

The motion analysis experiments for pregnant women during sitting down on chair and standing up from chair were performed using IMU. The present study was carried out in accordance with the guidelines of the Declaration of Helsinki, and the study protocol was reviewed and approved by the Ethics Committee of Kishokai Medical Corporation (approval number 2015_002). Written informed consent was obtained by all participants in accordance with the guidelines obtained by all participants in accordance with the guidelines.

2.1 Participants

Pregnant women were recruited from the obstetrics and gynecology clinics in Japan. The inclusion criteria were <12 weeks of pregnancy and a singleton pregnancy. Women with serious orthopedic disorders or neurological diseases and a high-risk pregnancy were excluded. Those with external injuries that affect the motion analysis were also excluded. Twenty-two pregnant women who met the inclusion criteria for the survey and agreed to participate in the study were enrolled. Among the participants, four complained about LPP (any of the three conditions: low back pain, pubic symphysis pain, and sacroiliac joint pain) during standing up from a chair. The demographic data of participants are shown in Table 1.

Subjects	All	LPP during standing up	Non LPP during standing up
Number of people	22	4	18
Age [years]	31.2 ± 4.6	32.3 ± 1.7	31.0 ± 5.0
Weeks ofpregnancy[week]	27.4 ± 9.2	25.5 ± 9.7	27.8 ± 9.4
Height [cm]	158.0 ± 5.7	157.5 ± 3.0	158.1 ± 6.2
Weight [kg]	56.0 ± 5.8	55.6 ± 3.4	56.1 ± 6.2

Table 1.Demographic characteristics of participants

Values, except for the number of people, are shown as mean ± standard deviation.

2.2 Measurement methods

As shown in Figure 1, all participants were evaluated using an inertial sensor incorporating tri-axis accelerometers, gyroscopes, and magnetometers (IMU: TSND121, ATR-Promotions Co., Ltd., Kyoto, Japan). An IMU was attached to a fixed belt at the level of the L3 spinous process, where the body's center of mass is thought to be located during quiet standing [19]. We can analyze motion, such as vibration and rotation of the human trunk, by acquiring data from the attached IMU. The signals were sampled at a frequency of 5 ms and were wirelessly and simultaneously transferred to apersonal computer via a Bluetooth personal area network. Figure 2 shows an overview of the measurement settings. A typical pipe chair was used in the analysis. Participants start at a standing position in front of the chair and perform sitting down and standing up, repeating each motion two times. We arranged the standstill period of approximately one second between each motion.

2.3 Measured data processing

Signal processing was performed for trunk angular velocity data using MATLAB (The MathWorks Co., Release 2016a, Tokyo, Japan). Figure 3 shows a definition of the coordinate system. Roll, pitch, and yaw angular velocity data were used in calculating the evaluation index for lateral bending, flexion/extension, and rotation of the trunk, respectively. The angular velocities of pitch data have a regular pattern and are used in the identification of the timing needed to change positions (sitting to standing, standing to sitting, and the static period when no movement occurs) during standing and sitting motion [18]. Thus, we identified the phrase of motion of sitting down and standing up based on the pitch waveforms. Figure 4 shows the time histories and index of pitch and yaw angular velocity. The pitch angular velocity moves normally from the plus direction to the minus direction in each

Figure 1. Appearance of sensor and experimental setting

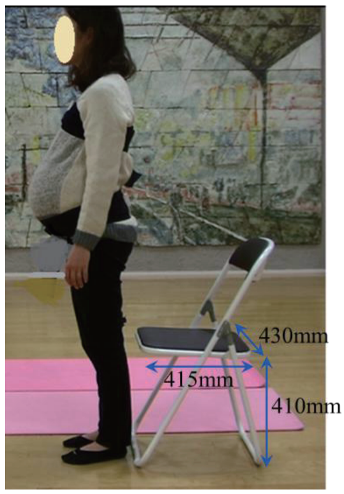

Figure 2. Experimental situation

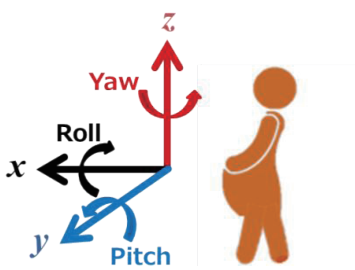

Figure 3. Coordinate system

sitting and standing motion. Using these characteristics, we estimated the shift point of the movement and the stopping state by detecting the before and after point of the maximum and minimum peaks of pitch angular velocity. In addition, the shift points were used in detecting the motion phrase for roll and yaw angular velocity.

3. PROPOSED MOTION EVALUATION INDEX FOR SITTING DOWN AND STANDING UP

The universal evaluation index calculated by angular velocity of the trunk movement during sitting and standing motion has not been established. In the current study, the following indexes were calculated to evaluate trunk movement during sitting and standing, as shown in Figure 4. Initially, the maximum and minimum peaks of each motion were detected; then, the peak-to-peak (PP) value was calculated from the difference of these two values. Next, the time between the maximum and minimum peaks was detected as the time of PP (Time of PP) value, and the value of PP divided by the time of PP (PP/Time of PP) was calculated. Then, the root mean square (RMS), which is used in expressing the effective value of the waveform, was calculated for each motion using the data of angular velocity { } by the following formula.

$$a_{RMS} = \left(\frac{\int_{t_1}^{t_n} a(t)^2 \, dt}{t_n - t_1} \right)^{\frac{1}{2}} \tag{1}$$

Lastly, each of the five parameters divided by body mass index (BMI) was calculated. Body weight changes greatly during pregnancy; hence, this characteristic should be considered in the evaluation of motion analysis. All indexes were calculated during both siting down and standing up for each roll, pitch, and yaw angle.

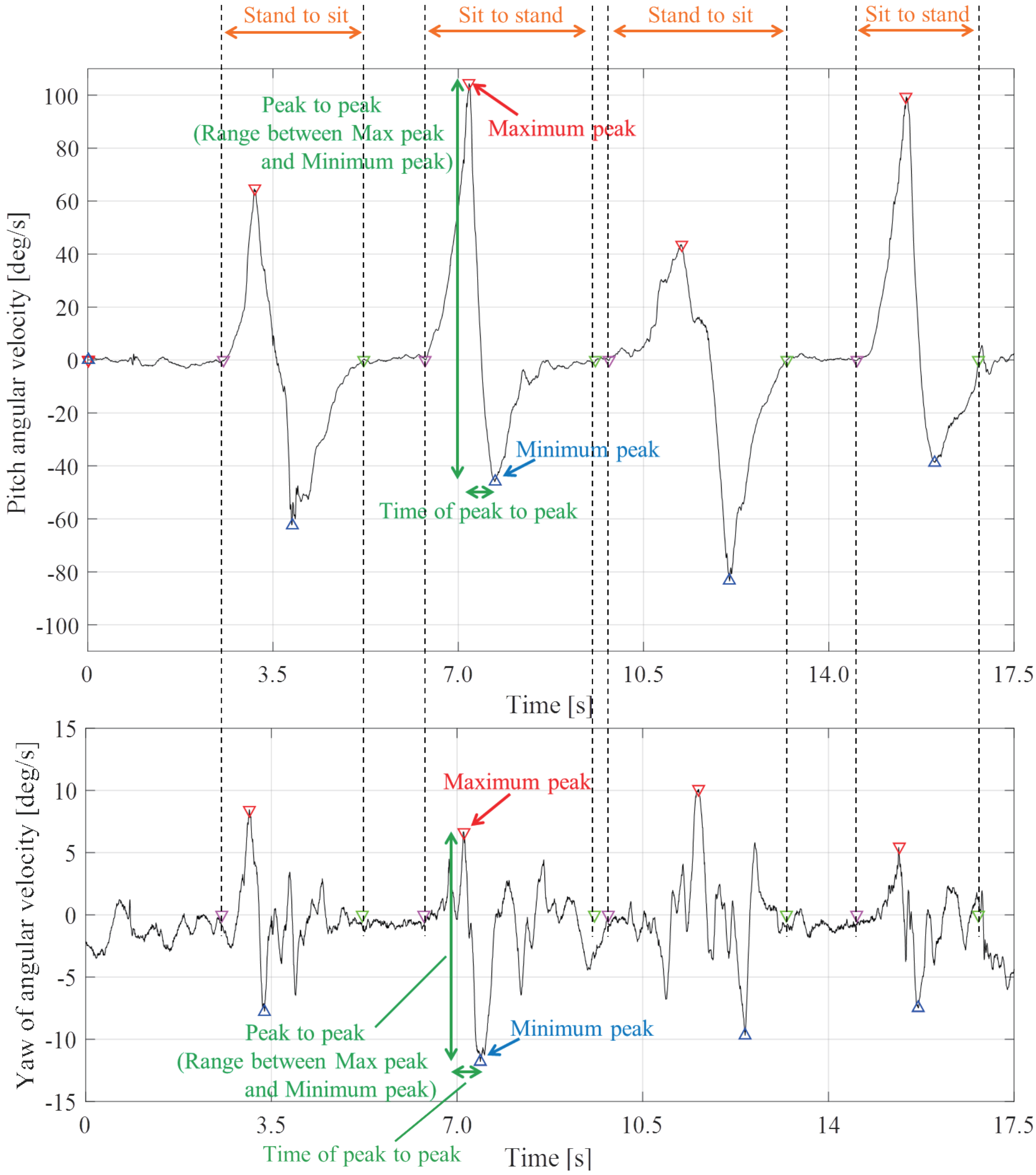

Figure 4. Time histories and index of pitch and yaw angular velocity.

4. ASSOCIATION BETWEEN THE PROPOSED MOTION EVALUATION INDEXES AND LPP DURING PREGNANCY

4.1 Statistical analysis

The participants were categorized into LPP and Non-LPP groups according to the presence or absence of LPP during standing up from chair. An independent t-test was conducted to investigate the differences in the motion evaluation indexes (Maximum peak, Minimum peak, PP, Time of PP, PP/Time of PP, RMS, Maximum peak/BMI, Minimum peak/BMI, PP/BMI, (PP/Time of PP)/BMI and RMS/BMI) of three axis during sitting down and standing up between the LPP and Non-LPP groups. Statistical analyses were performed using SPSS 23.0 (Chicago, IL, USA), with a significance threshold set at 0.05.

4.2 Results of analysis

The data of the proposed motion evaluation indexes for both the LPP and Non-LPP groups are shown in Table 2. In the LPP group compared with the Non-LPP group, Maximum peak, PP/Time of PP, Maximum peak/BMI, PP/BMI and (PP/Time of PP)/BMI of pitch angle during standing up motion were significantly greater.

Table 2 Difference of parameters according to the presence of lumbopelvic pain during stand up

		Stand to sit			Sit to stand		
	axis	LPP	Non-LPP	*p*-value	LPP	Non-LPP	*p*-value
Maximum peak [deg/s]	*x*	12.59 ± 5.81	12.25 ± 4.29	.894	9.74 ± 1.84	8.58 ± 2.70	.424
	y	41.03 ± 7.81	44.72 ± 12.26	.575	99.88 ± 1.95	73.23 ± 15.83	.004
	z	14.94 ± 5.53	15.76 ± 6.09	.807	11.79 ± 5.01	9.98 ± 4.30	.466
Minimum peak [deg/s]	*x*	-13.87 ± 6.82	-12.14 ± 5.03	.565	-11.48 ± 2.88	-8.67 ± 4.56	.256
	y	-77.56 ± 9.04	-71.13 ± 14.22	.401	-34.40 ± 4.39	-37.01 ± 11.05	.653
	z	-17.26 ± 1.87	-15.44 ± 5.44	.268	-13.97 ± 6.22	-11.58 ± 4.47	.375
PP [deg/s]	*x*	26.46 ± 12.28	24.39 ± 8.48	.687	21.23 ± 2.10	17.25 ± 6.16	.224
	y	118.59 ± 8.35	115.85 ± 21.61	.808	134.28 ± 5.29	110.24 ± 22.90	.054
	z	32.20 ± 5.83	31.20 ± 9.98	.850	28.87 ± 8.89	23.55 ± 7.02	.204
Time of PP [s]	*x*	0.60 ± 0.001	0.59 ± 0.003	.938	0.68 ± 0.30	0.90 ± 0.79	.600
	y	0.83 ± 0.001	1.07 ± 0.01	.483	0.67 ± 0.05	1.03 ± 1.02	.507
	z	0.48 ± 0.001	0.58 ± 0.003	.443	0.50 ± 0.24	0.69 ± 0.56	.522
PP / Time of PP [deg/s/s]	*x*	58.65 ± 28.25	58.03 ± 39.31	.977	46.21 ± 25.17	31.24 ± 0.24	.282
	y	162.61 ± 37.57	128.20 ± 45.12	.173	203.40 ± 8.20	157.34 ± 70.67	.015
	z	84.20 ± 18.37	82.19 ± 62.53	.951	74.08 ± 25.26	56.28 ± 0.43	.437
RMS	*x*	5.37 ± 2.71	4.37 ± 1.53	.314	3.53 ± 0.83	3.18 ± 0.12	.591
	y	29.16 ± 4.49	25.05 ± 5.91	.208	28.16 ± 6.89	22.31 ± 0.64	.120
	z	6.72 ± 1.00	6.00 ± 2.87	.632	4.63 ± 1.75	5.01 ± 0.37	.843
Maximum peak / BMI [deg/s/(kg/m^2)]	*x*	0.56 ± 0.27	0.54 ± 0.16	.810	0.43 ± 0.07	0.38 ± 0.13	.466
	y	1.83 ± 0.34	2.01 ± 0.56	.558	4.46 ± 0.16	3.31 ± 0.86	.000
	z	0.66 ± 0.23	0.70 ± 0.25	.806	0.53 ± 0.24	0.45 ± 0.20	.481
Minimum peak / BMI [deg/s/(kg/m^2)]	*x*	-0.62 ± 0.31	-0.53 ± 0.20	.482	-0.51 ± 0.14	-0.39 ± 0.20	.242
	y	-3.47 ± 0.49	-3.18 ± 0.61	.392	-1.53 ± 0.16	-1.67 ± 0.54	.371
	z	-0.77 ± 0.10	-0.69 ± 0.25	.539	-0.63 ± 0.28	-0.52 ± 0.19	.359
PP / BMI [deg/s/(kg/m^2)]	*x*	1.18 ± 0.57	1.07 ± 0.31	.582	0.95 ± 0.10	0.77 ± 0.28	.230
	y	5.30 ± 0.48	5.19 ± 0.96	.824	5.99 ± 0.19	4.98 ± 1.26	.004
	z	1.43 ± 0.23	1.39 ± 0.42	.830	1.29 ± 0.42	1.05 ± 0.33	.225
(PP / Time of PP) / BMI [(deg/s^2) / (kg/m^2)]	*x*	2.62 ± 1.28	2.59 ± 1.81	.976	2.04 ± 0.11	1.42 ± 0.12	.353
	y	7.27 ± 1.70	5.72 ± 1.97	.164	9.08 ± 0.33	7.15 ± 0.36	.038
	z	3.78 ± 0.92	3.66 ± 2.86	.938	3.32 ± 0.12	2.48 ± 0.17	.373
RMS / BMI	*x*	0.24 ± 0.12	0.19 ± 0.06	.248	0.16 ± 0.04	0.14 ± 0.05	.522
	y	1.31 ± 0.22	1.13 ± 0.29	.263	1.26 ± 0.31	1.01 ± 0.33	.182
	z	0.30 ± 0.04	0.27 ± 0.13	.620	0.21 ± 0.08	0.22 ± 0.14	.886

Values are shown as mean ± standard deviation.

LPP: Lumbopelvic pain during standing up, Non-LPP: Non-Lumbopelvic pain during standing up.

PP: Range between Maximum peak and Minimum peak, RMS: Root mean square, BMI: Body mass index.

In regards to PP of pitch angle during standing up, the similar tendency with the above five indexes was observed but not with significant differences. No significant differences of indexes of roll and yaw angle and during sitting down motion were observed from the analysis.

4.3 Discussions

Results show that no significant differences among indexes of roll and yaw angle were observed; therefore, the pitch angle that measures the flexion/extension of the trunk might be related to LPP. During the pregnancy, forward movement of the center of mass happens because of the abdominal swelling due to the fetus growth, and reduced posture stability and movement mainly occur in the anteroposterior direction [20]. Thus, it can be said that the difference of the movement strategy of the pitch angle led to physical stress.

The maximum peak was the index that represents the maximum velocity of the trunk during forward movement in the standing up motion from the chair. Thus, the greater maximum peak in the LPP group means that the movement properties that incline the trunk sharply forward during standing might produce a great load around the pelvis, and finally result in LPP. The PP was the index that represents the shift in degree change from the forward maximum incline speed (maximum peak) to the backward maximum incline speed (minimum peak). A significantly greater PP/Time of PP in the LPP group was observed; although the tendency was the same, no significant difference was observed in the PP. Hence, the movement strategy produced by a great change in a short time might be related to LPP. Therefore, consideration of the degree of change in movement speed, as well as the time required for it, might be important in the observation of standing up. In addition, significant differences were observed in the indexes that were divided by BMI, and it can be said that considering body weight is also important, especially for pregnant women.

5. CONCLUSIONS

In this study, we conducted motion analysis of sitting down and standing up for pregnant women using an IMU, and proposed the methods for identification of the phrase of sitting down and standing up from the angular velocity data. In the analysis, we attached an IMU at the level of the L3 spinous process of participants, where the body's center of mass is thought to be located during quiet standing and is thus a suitable position for measuring trunk movement. In addition, some indexes calculated from measured data of the lumbar angular velocity for evaluation of trunk movement during sitting down and standing up were also proposed. Lastly, we considered whether there is any relation between LPP and the motion characteristics by comparing the proposed motion evaluation indexes of the LPP group with those of the Non-LPP group. Thus, it appears that maximum peak, PP/Time of PP, maximum peak/BMI, PP/BMI, and (PP/Time of PP)/BMI of the pitch angle have some relevance to LPP. Therefore, the large motion of the pitch angle may be associated with the LPP of pregnant women during standing up. In addition, the results suggest that, when evaluating motion using an IMU, not only should the maximum values of angular velocity be assessed, but the required time for the motion and the BMI of pregnantwomen should also be considered. According to these results, it can be concluded that pregnant women should avoid great velocity in trunk movement to shift forward, as well as quick movement during standing up from a chair, to manage LPP.

6. ACKNOWLEDGMENTS

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ORIGINAL RESEARCH

Relationship Between Pedometer-Based Physical Activity and Physical Function in Patients With Osteoarthritis of the Knee: A Cross-Sectional Study

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Abstract

Objective: To examine the association between pedometer-based ambulatory physical activity (PA) and physical function in patients with knee osteoarthritis (OA).

Design: Cross-sectional observational study.

Setting: Institutional practice.

Participants: Participants in orthopedic clinics (N=207; age, 56–90y; 71.5% women) with diagnosed radiographic knee OA (Kellgren/Lawrence [K/L] grade ≥1).

Interventions: Not applicable.

Main Outcome Measures: Ambulatory PA was objectively measured as steps per day. Physical function was assessed using the Japanese Knee Osteoarthritis Measure (JKOM) functional subcategory, 10-m walk, Timed Up and Go (TUG), and 5-repetition chair stand (5CS) tests.

Results: Patients walking <2500 steps/d had a low level of physical function with a slower gait speed, longer TUG time, and worse JKOM functional score compared with those who walk 2500 to 4999, 5000 to 7499, and ≥7500 steps/d adjusted for age, sex, body mass index [BMI], and K/L grade. Ordinal logistic regression analysis revealed that steps per day (continuous) was associated with better physical function adjusted for age, sex, BMI, and K/L grade. These relationships were still robust in sensitivity analyses that included patients with K/L grades ≥2 (n=140).

Conclusions: Although increased ambulatory PA had a positive relationship with better physical function, walking <2500 steps/d may be a simple indicator for a decrease in physical function in patients with knee OA among standard PA categories. Our findings might be a basis for counseling patients with knee OA about their ambulatory PA and for developing better strategies for improving physical function in sedentary patients with knee OA.

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Physical activity (PA) is defined as any energy-consuming body movement produced by skeletal muscles.[1] Engaging in ambulatory PA is critical to long-term independent living for patients with knee osteoarthritis (OA), since walking disability increases cardiovascular mortality risk.[2] Furthermore, the U.S. federal government recommends increased PA for the general public.[3] However, most patients with knee OA are not physically active[4] and probably do not meet the recommended PA levels,[5-7] which reduces physical function. Physical function is related to the ability to move around and perform daily

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activities,[8] which is assessed using self-reported and performance-based measures.

A pedometer is a simple tool for objectively quantifying ambulatory PA (steps per day) and effectively motivates individuals with musculoskeletal disease to increase ambulatory PA.[9] An increase in steps per day is associated with better physical function in patients with knee OA, including improvements in gait velocity,[10] the Western Ontario and McMaster Universities Osteoarthritis Index functional measure,[10] and 6-minute walk distance.[11] However, many of the previous studies focused on the specific tests of physical function. The Osteoarthritis Research Society International recommends a set of performance-based tests of physical function that represents the typical activities relevant to individuals, such as short-distance walking, sit to stand, and ambulatory transitions.[12] Furthermore, self-reported and performance-based measures capture different aspects of physical function and offer complementary information.[13,14] Understanding the complex relationship between ambulatory PA and multiple measures of physical function would have important implications for counseling patients with knee OA about their PA and for developing better strategies for improving physical function in these patients.

To maximize the utility of pedometers as effective interventional tools for individuals, a framework is needed for classifying ambulatory PA into meaningful categories, and several studies have sought to identify a steps-per-day threshold for decline in physical function. Tudor-Locke et al[15] conducted an extensive literature review and suggested the standard ambulatory PA classification (ie, basal activity [<2500 steps/d], limited activity [2500−4999 steps/d], low active [5000−7499 steps/d], and physically active [≥7500 steps/d]).[16] Although they proposed that walking <5000 steps/d can be a step-defined sedentary lifestyle index in adults,[17] few studies have investigated the threshold of steps per day for a decline in physical function in patients with knee OA. White et al[10] showed that walking <5000 steps/d is associated with a decline in gait velocity over 2 years, and walking >3000 steps/d may be an initial minimum walking goal for patients with knee OA. Further studies are needed to establish potential threshold effects for discriminating between better or worse physical function as a minimum ambulatory PA goal in patients with knee OA.

This cross-sectional study aimed to examine the association of pedometer-based PA with physical function in patients with knee OA. We investigated these associations with steps per day as a continuous measure to determine the association between ambulatory PA and multiple functional measures, and as a categorical measure to identify a simple, standard threshold that indicates a decrease in physical function. We hypothesized that (1) there is a positive relationship between ambulatory PA and multiple functional measurements in both self-reported and performance-based measures; and (2) 5000 steps/d is a threshold for indicating a decline in physical function.

List of abbreviations:

BMI	**body mass index**
CI	**confidence interval**
5CS	**5-repetition chair stand**
JKOM	**Japanese Knee Osteoarthritis Measure**
K/L	**Kellgren/Lawrence**
OA	**osteoarthritis**
OR	**odds ratio**
PA	**physical activity**
TUG	**Timed Up and Go**

Methods

Participants

This cross-sectional study recruited previously treated patients with knee OA from community orthopedic clinics in Hiroshima and Kyoto, Japan, through advertising. The Kyoto University Ethics Committee approved the study (approval no. E1923). Written informed consent was obtained from all participants before enrollment. Supplemental figure S1 (available online only at http://www.archives-pmr.org/) presents the distribution of participants. Patients with radiographic OA (ie, Kellgren/Lawrence [K/L][18] grade ≥1) in 1 or both knees were included. Supplemental appendix S1 (methods 1 and 2; available online only at http://www.archives-pmr.org/) contains additional information on participants and radiographic assessment.

Measurement procedures

Pedometer-based ambulatory PA was evaluated for each participant. Furthermore, 1 OA-related health domain measure, including self-reported physical function (Japanese Knee Osteoarthritis Measure [JKOM]), and 3 performance-based functional tests (ie, the 10-m walk, Timed Up and Go [TUG], and 5-repetition chair stand [5CS] tests) were evaluated. All post-enrollment measurements were evaluated by trained physical therapists (H.I., N.F.) with >7 years of clinical experience with treating musculoskeletal disorders.

We used a pedometer[a] to evaluate free-living step counts because of its low cost, enhanced accessibility, and increased likelihood of use in clinical and public health applications. The JKOM subcategory of "activities of daily living" relies on daily activities such as stair use, bending, standing up from sitting, walking, shopping, removing socks, and light and heavy household duties.[19] For each subscale, higher scores indicate a worse condition (response: 0−4 points; Likert scale: 0, no pain or difficulty; 4, extreme pain or difficulty). The concurrent and construct validity of the JKOM was established by comparing with the Western Ontario and McMaster Universities Osteoarthritis Index and the Medical Outcomes Study 36-Item Short-Form Health Survey.[19] From the 10-m walk test, gait velocity (m/s), step length normalized to body height (percentage of body height), and cadence (steps/min) were calculated. For details, see supplemental appendix S1 (methods 3−5).

Statistical analyses

Data analyses were performed with JMP 11[b] or R.[c] Descriptive statistics were calculated as mean and SD for continuous variables and proportions for dichotomous/categorical variables. Patients were categorized into 4 step-based PA groups based on previously suggested cut points[16,17]: <2500 steps/d (basal activity), 2500−4999 steps/d (limited activity), 5000−7499 steps/d (low active), and ≥7500 steps/d (physically active). The required sample size in this study was 124 participants (see supplemental appendix S1, method 6). Demographic characteristics, radiographic OA status, and PA were compared among the 4 PA groups. The JKOM scores and performance-based physical function were also compared using an analysis of covariance or nonparametric rank analysis of covariance adjusted for age, sex, body mass index (BMI), and K/L grade, with post hoc pairwise comparisons using Bonferroni correction to reduce type I error. These covariates were chosen a priori based on clinical judgment. Parametric methods can result in inaccurate values when assumptions of normality and homogeneity of variance are not met.[20] Since the JKOM scores exhibited scattering distribution with a narrow range of score points, a nonparametric rank analysis of covariance[21] was used to compare the JKOM scores in each PA group. A scatterplot of PA and each physical function was also created.

Next, we performed an ordinal logistic regression analysis with each physical function (the JKOM subcategory "activities of daily living" score, free/fast gait velocity, TUG, and 5CS) as dependent variables and steps per day (continuous) as an independent variable (ie, in total, 5 ordinal logistic regression analyses were performed). Ordinal logistic regression is a popular model for ordinal categorical outcome variables, which also works well for skewed continuous outcome variables using ranks of data.[22] In the ordinal logistic regression models, each physical function was categorized into 4 groups by quartiles (<25th percentile, 25th to 50th percentile, 50th to 75th percentile, ≥75 percentile) and treated as ordinal variables (1−4; 1 [<25th percentile] indicates worse function, and 4 [≥75 percentile] indicates higher function). Results were presented as an odds ratio (OR) with a 95% confidence interval (CI) per 1000 steps after being adjusted for age (continuous), sex (0, male; 1, female), BMI (continuous), and K/L grade (continuous). We chose 1000 steps/d as an increment that is more reasonable and interpretable than a single step.

Sensitivity analyses were performed to assess whether the relationship between PA and physical function is influenced by a subsample index knee K/L grade ≥2. In these analyses, we replicated the ordinal logistic regression analysis, as mentioned earlier. *P* values <.05 were considered statistically significant.

Results

In total, 225 patients were initially enrolled; however, 18 were excluded because of incomplete clinical data. Fifty-eight (28.0%) of the remaining 207 patients (see supplemental fig S1) were classified in the basal activity group, 79 (38.2%) in the limited activity group, 45 (21.7%) in the low-active group, and 25 (12.1%) in the physically active group. Overall, patients in the basal activity group were significantly older and had more severe tibiofemoral OA (K/L grade ≥3) than did the other 3 groups (table 1), whereas other demographic characteristics were not significantly different among the 4 groups.

Comparison of JKOM score, spatiotemporal gait parameter, TUG, and 5CS among the 4 PA groups

Patients in the basal activity group had a significantly higher score (ie, worse self-reported physical function) of "activities of daily living" (11.2±7.38 points) than did those in the other 3 groups (table 2) when adjusted for age, sex, BMI, and K/L grade. Further, patients in the basal activity group had significantly higher scores for "total score" (ie, lower quality of life) than did those in the physically active group when adjusted for age, sex, BMI, and K/L grade. There were no significant differences of any JKOM subcategory scores among the limited activity, low-active, and physically active groups.

In general, patients in the basal activity group had the worst spatiotemporal gait parameters (eg, gait velocity: .98±.18m/s) and took significantly longer to perform the TUG test (9.76±2.35s) than did those in the other 3 groups, even after adjusting for age, sex, BMI, and K/L grade (table 3). There were no significant

Table 1 Comparisons of patients' demographic characteristics, OA severity, and PA (N=207)

Variables	Basal Activity (<2500 Steps) (n=58)	Limited Activity (2500−4999 Steps) (n=79)	Low Active (5000−7499 Steps) (n=45)	Physically Active (≥7500 Steps) (n=25)	*P**
Age (y)	76.4±8.89	73.4±6.83	70.0±6.48†	70.4±6.00†	<.001‡
Female	46 (79.3)	57 (72.2)	31 (68.9)	14 (56.0)	.184
Height (m)	1.54±0.06	1.55±0.08	1.57±0.07	1.57±0.08	.065
Weight (kg)	58.5±10.8	58.3±10.8	59.6±9.60	58.6±10.0	.766
BMI (kg/m²)	24.8±4.58	24.1±3.86	24.0±3.28	23.7±3.31	.812
Anatomic axis angle (deg)	180.1±5.47	181.4±4.09	181.2±4.04	182.2±3.27	.212
Tibiofemoral joint K/L grade					.022‡
1	12 (20.7)	27 (34.2)	15 (33.3)	13 (52.0)	
2	18 (31.0)	31 (39.2)	19 (42.2)	8 (32.0)	
3	21 (36.2)	13 (16.5)	4 (8.9)	3 (12.0)	
4	7 (12.1)	8 (10.1)	7 (15.6)	1 (4.0)	
PA					
Average daily walking (steps/d)	1711±591	3718±754†	5808±701†,§	9858±2132†,§,‖	<.001‡
SD of daily walking (steps/d)	978±593	1679±777†	2224±928†,§	3408±1550†,§,‖	<.001‡
CV of daily walking (%)	59.3±27.4	45.8±20.9†	38.5±16.1†	35.4±17.2†	<.001‡

NOTE. Values are mean ± SD, n (%), or as otherwise indicated.
Abbreviation: CV, coefficient of variation.
* Based on unadjusted analysis (Kruskal-Wallis [age, height, weight, BMI, anatomic axis angle, and PA] or Fisher exact tests [female and tibiofemoral joint K/L grade]) among the 3 groups. In these analyses, JMP 11 (Kruskal-Wallis test) software and R (Fisher exact test) software were used. Nonnormality of continuous variables, analyzed using Kruskal-Wallis test, are assessed with the Shapiro-Wilk test (*P*<.05).
† Significantly different (*P*<.05) from the basal activity group based on the post hoc Steel-Dwass test.
‡ Statistically significant result.
§ Significantly different (*P*<.05) from the limited activity group based on the post hoc Steel-Dwass test.
‖ Significantly different (*P*<.05) from the low-active group based on the post hoc Steel-Dwass test.

Table 2 Comparisons of JKOM including self-reported physical function using rank ANCOVA (N=207)

JKOM Scores	Basal Activity (<2500 Steps) (n=58)		Limited Activity (2500–4999 Steps) (n=79)		Low Active (5000–7499 Steps) (n=45)		Physically Active (≥7500 Steps) (n=25)		Adjusted P*
Pain and stiffness (0–32 points)	10.3±6.18	9 (0–27)	8.22±6.00	7 (0–22)	7.47±5.40	7 (0–24)	6.52±4.95	6 (0–20)	.404
Activities of daily living (0–40 points)	11.2±7.38	11.5 (0–31)	6.42±5.67†	5 (0–24)†	5.62±5.89†	3 (0–29)†	3.72±4.52†	2 (0–17)†	<.001‡
Participation in social activities (0–20 points)	5.28±4.84	4 (0–19)	3.14±2.54	3 (0–12)	2.87±3.20	1 (0–11)	1.68±2.14	1 (0–9)	.023‡
General health conditions (0–8 points)	3.52±1.84	3 (0–8)	2.85±1.43	3 (0–6)	2.84±1.54	3 (0–6)	2.32±1.22	2 (1–5)	.058
Total score (0–100 points)	30.2±16.5	25 (5–65)	20.6±13.6	17 (1–55)	18.8±13.5	16 (1–62)	14.2±11.0†	12 (1–42)†	.004‡

NOTE. Values are mean ± SD, median (lower range–upper range), or as otherwise indicated. Median (lower range–upper range) JKOM scores were calculated because of the scattered distribution of the answered items.

Abbreviation: ANCOVA, analysis of covariance.

* Adjusted P values were calculated from the rank ANCOVA adjusted for age, sex, BMI, and radiographic tibiofemoral joint K/L grade.

† Significantly different ($P<.0083$ [.05/6]) from the basal activity group when adjusted for age, sex, BMI, and radiographic tibiofemoral joint K/L grade as a post hoc test of rank ANCOVA.

‡ Statistically significant result.

differences of any performance-based physical function among the limited activity, low-active, and physically active groups.

Association of steps per day as a continuous variable with JKOM score, spatiotemporal gait parameter, TUG, and 5CS

A scatterplot of PA and each physical function is shown in supplemental figure S2 (available online only at http://www.archives-pmr.org/), which indicates that there is a positive relationship between ambulatory PA and functional measures. To further illustrate the association between steps per day and each functional measure, we performed ordinal logistic regression analysis (table 4). Quartiles in each functional measure are provided in supplemental table S1 (available online only at http://www.archives-pmr.org/). The results (see table 4) indicated that an increase in steps per day was significantly associated with higher odds of a greater quantile (ie, better physical function) in the JKOM subcategory "activities of daily living" score (OR=1.26 per 1000 steps; 95% CI, 1.13–1.40; $P<.001$), free gait velocity (OR=1.19 per 1000 steps; 95% CI, 1.07–1.32; $P=.001$), fast gait velocity (OR=1.18 per 1000 steps; 95% CI, 1.06–1.31; $P=.002$), and time in the TUG (OR=1.33 per 1000 steps; 95% CI, 1.18–1.49; $P<.001$) and 5CS (OR=1.22 per 1000 steps; 95% CI, 1.10–1.36; $P<.001$) after being adjusted for age, sex, BMI, and K/L grade.

Sensitivity analyses were performed to address the possibility that the relationship of PA with physical function was influenced by the subsample of patients with K/L grades ≥2 (n=140; supplemental table S2 [available online only at http://www.archives-pmr.org/]). Ordinal logistic regression analysis indicated that an increase in steps per day was significantly associated with higher odds of a greater quantile (ie, better physical function) in the JKOM subcategory "activities of daily living" score (OR=1.14 per 1000 steps; 95% CI, 1.01–1.30; $P=.035$), free gait velocity (OR=1.16 per 1000 steps; 95% CI, 1.02–1.32; $P=.020$), fast gait velocity (OR=1.20 per 1000 steps; 95% CI, 1.06–1.37; $P=.005$), and time in the TUG (OR=1.38 per 1000 steps; 95% CI, 1.18–1.61; $P<.001$) and 5CS (OR=1.24 per 1000 steps; 95% CI, 1.08–1.42; $P=.002$), after being adjusted for age, sex, BMI, and K/L grade, which is consistent with the result shown in table 4.

Discussion

We examined the association of step-based standard 4 PA groups with physical function in patients with knee OA to establish a steps-per-day threshold as an indicator of decline in physical function, and examined the relationship between PA and function using ordinal logistic regression analysis. An increase in steps per day was significantly associated with better self-reported and performance-based functional measures (see table 4), which supports our first hypothesis. Notably, contrary to our second hypothesis that 5000 steps/d would be a threshold for indicating a decline in physical function, patients walking <2500 steps/d were found to have functional limitations including a slower gait speed, longer TUG time, and higher JKOM functional score compared with the more active groups (see tables 2 and 3).

The strength of the current study is the evaluation of the relationship between standard ambulatory PA categories and physical function in patients with knee OA. Tudor-Locke[16]

Table 3 Comparisons of performance-based physical function using ANCOVA (N=207)

Performance-based Physical Function	Basal Activity (<2500 Steps) (n=58)	Limited Activity (2500–4999 Steps) (n=79)	Low Active (5000–7499 Steps) (n=45)	Physically Active (≥7500 Steps) (n=25)	Adjusted *P**
Spatiotemporal gait parameters					
Free gait velocity (m/s)	0.98±0.18	1.15±0.17†	1.17±0.19†	1.22±0.19†	<.001‡
Free step length (% height)	32.6±4.81	36.2±5.00†	35.4±5.45†	37.8±4.06†	.002‡
Free cadence (steps/min)	117.2±12.6	123.6±11.5†	126.0±12.8†	124.0±14.7†	.001‡
Fast gait velocity (m/s)	1.23±0.27	1.45±0.26†	1.50±0.27†	1.58±0.29†	<.001‡
Fast step length (% height)	34.8±5.60	38.4±6.21	39.3±6.79	41.1±5.21	.064
Fast cadence (steps/min)	137.7±18.1	147.1±18.1†	146.2±16.7†	147.7±21.3†	.026‡
TUG (s)	9.76±2.35	8.11±1.54†	7.56±2.31†	7.04±1.31†	<.001‡
5CS (s)	10.5±3.42	9.06±2.33	8.55±2.86	7.90±1.74	.083

NOTE. Values are mean ± SD or as otherwise indicated.
Abbreviation: ANCOVA, analysis of covariance.
* Adjusted *P* values were calculated from ANCOVA adjusted for age, sex, BMI, and radiographic tibiofemoral joint K/L grade.
† Significantly different (*P*<.0083 [.05/6]) from the basal activity group adjusted for age, sex, BMI, and radiographic tibiofemoral joint K/L grade as a post hoc analysis of ANCOVA.
‡ Statistically significant result.

suggested the standard ambulatory PA classification after extensive review,[15] and proposed that walking <5000 steps/d can be a step-defined sedentary lifestyle index associated with cardiometabolic risk factors in healthy adults.[17] A recent prospective cohort showed that walking <5000 steps/d increases the risk of gait speed decline by 2- to 3-fold after 2 years in patients with knee OA,[10] thereby indicating that 5000 steps/d is a potential simple PA target for maintaining physical function for patients with knee OA. However, we found that patients walking 2500 to 4999 steps/d did not differ in functional measurements from those walking 5000 to 7499 or ≥7500 steps/d. Rather, a cutoff of 2500 steps/d, the basal level of activity for healthy adults,[16] could better identify worse physical function in patients with knee OA (see graphical abstract). Our findings reinforce previous studies showing a threshold effect of ambulatory PA on physical function.[10,23] White[10] identified a threshold of 3000 steps/d as having a high specificity for predicting functional limitation 2 years later. Furthermore, Taniguchi et al[23] reported that walking >3000 steps/d is a predictor of better TUG time at 6 months after total knee arthroplasty, thereby indicating that walking 2500 to 3000 steps/d may be a minimum initial goal for preventing long-term poor function.

Table 4 Association of steps per day with quartile of self-reported/performance-based physical functions according to ordinal logistic regression analysis (N=207)

Dependent Variables	OR (95% CI) per 1000 Steps	*P*
JKOM subcategory "activities of daily living" (points)	1.26 (1.13–1.40)*	<.001*
Free gait velocity (m/s)	1.19 (1.07–1.32)*	.001*
Fast gait velocity (m/s)	1.18 (1.06–1.31)*	.002*
TUG (s)	1.33 (1.18–1.49)*	<.001*
5CS (s)	1.22 (1.10–1.36)*	<.001*

NOTE. OR (95% CI) for a greater quartile of each dependent variable was calculated per 1000 steps/d (continuous) to indicate their predictive ability while simultaneously including (1-step model) age (continuous), sex, BMI (continuous), and radiographic tibiofemoral joint K/L grade (continuous) in the ordinal regression model. Each dependent variable was categorized into a 4-level ordinal scale (1–4) defined by quartile (1 [<25th percentile] indicates worse function, and 4 [≥75 percentile] indicates higher function). See supplemental table S1 for details of quartiles in each functional measure.
* Statistically significant result.

An active lifestyle is associated with a higher gait speed and a better Western Ontario and McMaster Universities Osteoarthritis Index functional measure.[10,24] Furthermore, PA intervention improves walking performance and lower extremity muscle strength.[25,26] Our finding of a positive relationship between PA and better physical function (see table 4) supports these reports. Furthermore, these relationships were still robust when using subsamples with patients with K/L grade ≥2, thereby indicating that the relationship of PA with physical function is not affected by including patients with a K/L grade of 1. The *2008 Physical Activity Guidelines for Americans*[3] suggests that "some is good; more is better." However, given that most patients with knee OA are not physically active[4] and are less likely than adults without OA to meet the recommended PA levels,[5-7] promoting potentially difficult to achieve PA without minimal goals would further discourage patients with knee OA and could deter rehabilitation. PA is clearly a continuous measure; thus, it may be hard to define a clear threshold for a decline in physical function. However, using standard PA categories such as <2500 steps/d might be helpful in determining minimal, realistic PA goals even in sedentary patients with knee OA.

Another strength of the current study is the comprehensive evaluation of the relationship between ambulatory PA and multiple functional measurements including both self-reported and performance-based measures. It has been argued that self-reported and performance-based measures capture different aspects of physical function and offer complementary information,[13,14] and self-reported measures are more influenced by knee pain than are performance-based measures in patients with knee OA.[27] We confirmed that the positive relationship between the steps per day and JKOM "activities of daily living" was attenuated when knee pain (JKOM "pain and stiffness") was further included in the ordinal logistic regression model (data not shown), indicating a substantial role of knee pain on the relationship between ambulatory PA and self-reported measures. On the other hand, performance-based measures have advantages over self-report measures, including reduced influence of knee pain and more reflection of ability to complete daily activities, although these may be primarily assessing only 1 core domain of physical function. Terwee et al[28] conducted an extensive review and suggested that multiple performance-based tests are more valid for measuring physical function than a single test, because patients with OA have functional limitation in the several daily activities beyond just walking. Our study clarified the relationship of steps per day with each functional domain (short-distance walking, ambulatory transitions, and sit to stand) as well as self-reported measures, which would be a basis for developing a better PA intervention and would be helpful in choosing an appropriate functional assessment in patients with knee OA.

Study limitations

Since this was a cross-sectional study, we cannot comment on the causal relationships between PA and physical function. It is also possible that the unequal sample sizes of the step-based PA groups may produce a type I error. Since we analyzed the index knee in mixed patients with radiographic and symptomatic OA, it is possible that knee pain restricted physical function, particularly self-reported physical function. However, the prospective effects of steps per day for predicting functional limitation were similar for patients with either radiographic or symptomatic OA.[10] Furthermore, similar results were obtained even after including knee pain in the multiple regression models (data not shown). Additionally, pedometer-based steps per day is a simple and accurate indicator of ambulatory PA[29,30]; however, it does not evaluate PA intensity and does not characterize nonambulatory activities (eg, cycling and swimming). Nevertheless, the pedometer is less expensive, more readily accessible, and used in clinical practice,[9] and ambulatory PA is fundamental to basic human mobility across all domains of daily living. Furthermore, an assessment based on steps per day would be useful for clinicians and for communicating with the general public,[17] and this study is the first to clarify a potential steps-per-day threshold as an indicator of decline in physical function in patients with knee OA by using a pedometer-based standard PA category. While we did not monitor pedometer time, 10 hours is needed to identify a valid day in adults with knee OA.[31] Sufficient monitoring time facilitates identifying an exact relationship between PA and function. Finally, it is unclear whether 2500 steps/d is the most accurate threshold for indicating a decline in physical function, although we used the previously suggested cut points as step-based PA categories, and walking <2500 steps/d is known to be associated with a higher prevalence of metabolic syndrome relative to more active PA categories.[32] Alternative thresholds may be more valid; however, these have not been used extensively and lack confirmation. Since standardized definitions would facilitate comparisons among relevant studies, additional research is warranted to illuminate the appropriateness of standard PA classifications.

Conclusions

We examined the comprehensive relationship between ambulatory PA and multiple physical function. Participants who walked <2500 steps/d had a low level of physical function with a slower gait speed, longer TUG time, and higher JKOM functional score, thereby indicating a potential steps-based threshold of 2500 steps/d as an indicator of decline in physical function in adults with knee OA. These findings might be a basis for developing better strategies for improving physical function in these patients.

Suppliers

a. Yamax Power Walker EX-300; Yamasa Tokei Keiki Co, Ltd.
b. JMP 11; SAS Institute Inc.
c. R; Foundation for Statistical Computing; available at: http://www.R-project.org.

Keywords

Osteoarthritis; Physical fitness; Rehabilitation

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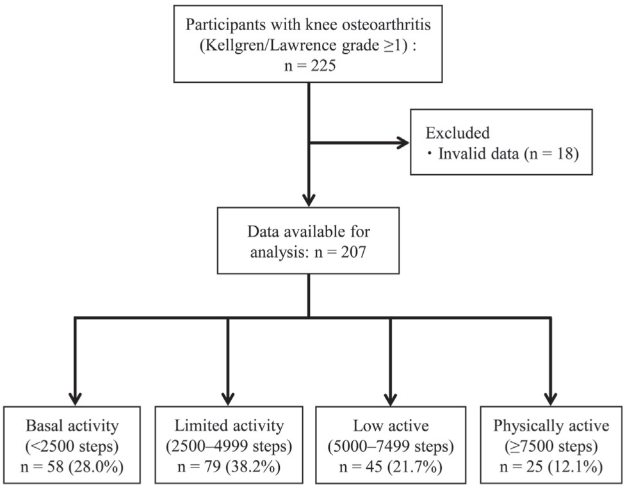

Supplemental Fig S1 Flow chart describing the distribution of study patients with knee OA. All recruited patients had a history of pain in 1 or both knees. We used data from 12-month visits between January 2014 and January 2015 to assess the outcome data in order to maximize the number of patients with knee OA. In total, 225 patients were initially enrolled; however, 18 were excluded because of incomplete clinical data. The remaining 207 patients (92.0% of the initial cohort) were included in the final analysis. Of 207 patients, 7 (3.4%) exhibited lateral knee OA, and 17 (8.2%) did not experience knee pain (JKOM "pain and stiffness" score, 0).

Supplemental Appendix S1 Additional Information About Methods

Method 1: Eligibility and exclusion criteria of study participants

The eligibility criteria included the following: (1) age ≥50 years; (2) knees with radiographic OA (ie, K/L[1] grade ≥1) in 1 or both knees, as evaluated by weight-bearing anteroposterior radiographs; and (3) an ability to walk independently on a flat surface without any ambulatory assistive device. Since pre-radiographically defined knee OA, particularly K/L grade 1, predicts radiographic OA progression to at least grade 2,[2,3] we included patients with K/L grades ≥1. Both patients with bilateral or unilateral knee OA were considered. Patients were excluded if they had (1) a history of knee surgery; (2) inflammatory arthritis; (3) periarticular fracture; or (4) current neurologic problems.

Method 2: Radiographic examination of OA severity and tibiofemoral joint alignment

Radiographic OA severity of the "index knee" in each patient was assessed in the anteroposterior short view in the weight-bearing position by an experienced examiner (T.A.) using the K/L grading system. The index knee was defined as the more painful knee in either the past or present. If the patient reported equal pain, the index knee was randomly selected. A single trained examiner (H.I.) evaluated the anatomic axis angle, which was defined as the internal angle formed by the intersection of 2 lines originating from points bisecting the femur and tibia, and converging at the center of the tibial spine tips, by using anteroposterior radiography. To assess intrarater reliability, 100 randomly selected radiographs were scored again by the same examiner (OA severity: T.A.; measurement of anatomic axis angle: H.I.) more than 1 week after the first assessment. The intrarater reliability scores were excellent for radiographic OA severity (κ=.90) and measurement of anatomic axis angle (intraclass correlation coefficient =.98).

Method 3: Pedometer-based evaluation of ambulatory PA

We used a pedometer[a] to evaluate free-living step counts because of its low cost, enhanced accessibility, and increased likelihood of use in clinical and public health applications. This pedometer gave mean step counts that were within 3% of actual steps[4] and validated in free-living conditions.[5] Each patient received a pedometer with instructions and an activity calendar for recording data. Patients were asked to wear the pedometer in the pocket of their dominant leg for 14 consecutive days and to remove it when bathing, sleeping, or performing water-based activities. The participants were asked to record the number of steps at the end of each day, and completed activity calendars were returned via mail after 14 consecutive days. The sample was restricted to patients who wore the pedometer for at least 10 days, which is more than enough to reliably estimate PA (ie, 3d).[6] We then calculated the average steps per day. To assess intraindividual variation in daily steps for each patient, we calculated the SD of steps and the coefficient of variation of steps ([SD/average steps per day] × 100) during the monitoring days.

Method 4: The JKOM

The JKOM is a patient-based, self-answered evaluation scoring system that assesses "pain and stiffness" (8 questions, 0–32 points), "activities of daily living" (10 questions, 0–40 points), "participation in social activities" (5 questions, 0–20 points), and "general health conditions" (2 questions, 0–8 points), with a maximum score of 100 points in a person-specific assessment. The JKOM subcategory of "activities of daily living" relies on daily activities such as stair use, bending, standing up from sitting, walking, shopping, removing socks, and light and heavy household duties. For each subscale, higher scores indicate a worse condition (response: 0–4 points; Likert scale: 0 indicates no pain or difficulty, and 4 represents extreme pain or difficulty). The concurrent and construct validity of the JKOM was established by comparing with the Western Ontario and McMaster Universities Osteoarthritis Index and the Medical Outcomes Study 36-Item Short-Form Health Survey.[7]

Method 5: Spatiotemporal gait parameters (gait speed, step length, and cadence), TUG, and 5CS

We assessed objective performance-based physical function based on identified activities recommended by the Osteoarthritis Research Society International as follows: short-distance walking, sit to stand, and ambulatory transitions.[8] Patients were instructed to walk 10m at 2 self-selected speeds: "free" (self-selected speed) and "fast" (at maximal gait speed). We measured the time with a stopwatch and the number of steps required to walk 10m at each speed.[9] The following spatio-temporal gait parameters were calculated manually for both speeds: gait velocity (m/s), step length normalized to body height (percentage of body height), and cadence (steps/min). The TUG test,[10] a simple, common, and reliable test for clinical use in individuals with or at risk of developing knee OA, was performed.[11] Patients were instructed to rise from a chair, walk 3m, turn around, return, and sit down as fast as possible. The time was measured using a stopwatch. Furthermore, the 5CS test, which measures the time required for 5 repetitions of rising from a chair and sitting down as fast as possible, was evaluated. The TUG and 5CS tests can be feasibly used by clinicians.[8]

Method 6: Required sample size

A sample size calculation was performed using the sample size and power tool in the JMP 11 software.[b] Since there was no report that compares functional measurements among the 4 step-based PA groups, we used pilot data including the first 5 participants in each step-based PA group (ie, 20 participants in total). The free gait velocity $\pm$ SD was 1.03$\pm$.19m/s in the basal activity group, 1.17$\pm$.06m/s in the limited activity group, 1.18$\pm$.14m/s in the low-active group, and 1.23$\pm$.16m/s in the physically active group. With a power of .80 and a significance level of $P<.0083$ (.05/6), at least 112 participants were required across the 4 groups. Accounting for a potential 10% dropout rate because of exclusion criteria and invalid data, 124 participants were targeted for this study, a number that was sufficient for detecting statistically significant differences in free gait velocity among the 4 PA groups.

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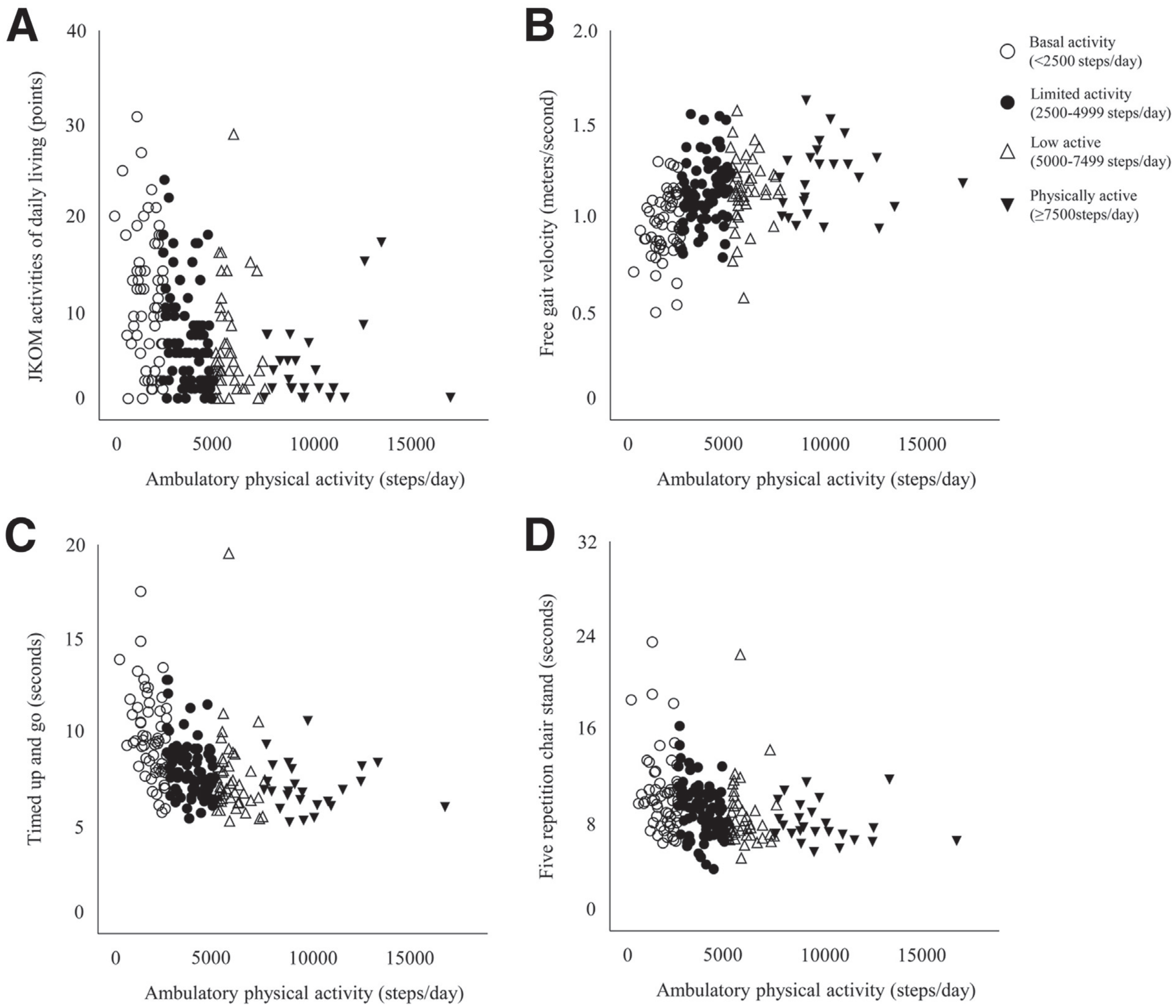

Supplemental Fig S2 Comparison of scatterplots of PA and physical function. (A) PA and JKOM activities of daily living. (B) PA and free gait velocity. (C) PA and time of TUG. (D) PA and 5CS. Scatterplots of PA and the other spatiotemporal parameter of free gait and those of fast gait are not shown in this figure.

Supplemental Table S1 Quartiles of each functional measure (greater quartile indicates better physical function) in the study patients

Variables	Quartile			
	<25th Percentile	25th—50th Percentile	50th—75th Percentile	≥75th Percentile
JKOM subcategory “activities of daily living” (points)	31—11	10—5	4—2	1—0
Free gait velocity (m/s)	0.50—0.97	0.98—1.12	1.13—1.23	1.24—1.65
Fast gait velocity (m/s)	0.66—1.21	1.22—1.41	1.42—1.58	1.59—2.39
TUG (s)	19.7—9.28	9.27—7.94	7.93—6.78	6.77—5.12
5CS (s)	23.7—10.6	10.5—8.68	8.67—7.22	7.21—3.96

Supplemental Table S2 Association of steps per day with quartile of self-reported/performance-based physical functions according to ordinal logistic regression analysis in patients with K/L grade ≥2 (n=140), which indicates that these associations are comparable regardless of radiographic knee OA definition (K/L grade ≥1 or ≥2)

Dependent Variables	OR (95% CI) per 1000 Steps	*P*
JKOM subcategory "activities of daily living" (points)	1.14 (1.01–1.30)*	.035*
Free gait velocity (m/s)	1.16 (1.02–1.32)*	.020*
Fast gait velocity (m/s)	1.20 (1.06–1.37)*	.005*
TUG (s)	1.38 (1.18–1.61)*	<.001*
5CS (s)	1.24 (1.08–1.42)*	.002*

NOTE. OR (95% CI) for a greater quartile of each dependent variable was calculated per 1000 steps/d (continuous) to indicate their predictive ability while simultaneously including (1-step model) age (continuous), sex, BMI (continuous), and radiographic tibiofemoral joint K/L grade (continuous) in the ordinal regression model. Each dependent variable was categorized into a 4-level ordinal scale (1–4) defined by quartile (1 [<25th percentile] indicates worse function, and 4 [≥75 percentile] indicates higher function). ORs and 95% CIs in this supplemental table S2 are similar to those in table 4 (see table 4 for details).

* Statistically significant result.

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Research Article

Open Access

Comparison of Pelvic Alignment among Never-Pregnant Women, Pregnant Women, and Postpartum Women (Pelvic Alignment and Pregnancy)

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Abstract

Objective: To compare the pelvic alignment among never-pregnant women, pregnant women, and postpartum women.

Methods: A total of 177 nulliparous women (mean age, 18.9 ± 1.0 years), 45 pregnant women between the third and tenth month of pregnancy (mean age, 29.4 ± 3.8 years), and 124 primiparous women between the first and sixth months after delivery (mean age, 30.1 ± 4.4 years) were enrolled in this study. Pelvic alignment was measured by using the anterior superior iliac spine (ASIS) and posterior superior iliac spines (PSIS) as landmarks. The bilateral difference of pelvic tilt was defined as pelvic asymmetry (PA), the distance between bilateral ASIS was defined as the anterior width of the pelvis (AWP), and the distance between the bilateral PSIS was defined as the posterior width of the pelvis (PWP).

Results: PA of the pregnant group and postpartum group were significantly greater than the never-pregnant group (2.8 ± 2.4°, 4.2 ± 3.0°, and 3.7 ± 3.2°, respectively, $p < 0.001$). AWP of the pregnant and postpartum group was wider than the never-pregnant group (24.9 ± 0.3 cm, 24.1 ± 0.1 cm, and 23.6 ± 0.2 cm, respectively, $p < 0.001$). PWP of the pregnant and postpartum group was narrower than the never-pregnant group (8.2 ± 0.3 cm, 8.6 ± 0.1 cm, and 9.2 ± 0.1 cm, respectively, $p = 0.008$). In the multivariate regression analysis using never-pregnant women as the reference, pregnant and postpartum women were significantly more likely to have greater PA ($\beta = 0.156, 0.156$), wider AWP ($\beta = 0.116, 0.202$), and narrower PWP ($\beta = -0.132, -0.147$) than never-pregnant women.

Conclusions: We found that the alignment of the pelvis was different among never-pregnant, pregnant, and postpartum women.

Keywords: Nulliparous women; Pregnant women; Postpartum women; Pelvic alignment; Pelvic asymmetry; Anterior width of pelvis; Posterior width of pelvis

Introduction

The alignment of the pelvis is an important topic in the perinatal period. During pregnancy and delivery, pelvic joints undergo changes due to the pregnancy-related hormonal influences and mechanical stresses such as pregnancy-related abdominal swelling [1]. In a previous study, pelvic alignment was associated with pregnancy-related lumbopelvic pain and pelvic floor muscle characteristics [2-5]. Therefore, pelvic alignment is important for pregnant and postpartum women.

The pregnancy-related hormones have anti-fibrotic properties and affect the ligaments and bone in the pelvic region, and the pelvic joints gain laxity [6]. Ligamentous relaxation by pregnancy-related hormones provides relative mobility of the pubic symphysis and sacroiliac joint synchondroses, resulting in widening of the birth canal and facilitating delivery [7-9]. After delivery, laxity of these ligaments gradually diminishes [1]. In some deliveries, the pubic rami separated widely because the ratio of the diameter of the maternal pelvis to the fetal head is too small to allow normal delivery [7]. A previous study showed that the distance of the interpubic gap of postpartum women was larger than that of nulliparous women [10]. Thus, alignment changes of the pelvis in the frontal plane occur during delivery.

Due to relaxation of the pelvic joints and pregnancy-related abdominal swelling, pelvic alignment in the sagittal plane changes in pregnant women. Ostgaard et al. reported that the pregnant pelvis had an anterior inclination [3], while Moore et al. reported the pelvis had a posterior inclination [4]. Thus, alignment of the pelvis in the sagittal plane has not been fully confirmed. On the other hand, Franklin et al. reported that the degree of inclination of the pelvis was different between the right and left sides during pregnancy [11]. Therefore, the pelvis might be positioned with left-right asymmetry during pregnancy. This asymmetric pelvis has been reported only in pregnant women before delivery.

There have been many studies about the pelvic alignment of women during pregnancy and delivery [3,4,7-9,11]; however, there are few studies about the differences in pelvic alignment over the course

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of pregnancy and delivery. Therefore, the purpose of this study was to compare the pelvic alignment of never-pregnant women, pregnant women, and postpartum women in a cross-sectional study.

Methods

Subjects

A total of 177 nulliparous non-pregnant women (mean age, 18.9 ± 1.0 years), 45 nulliparous pregnant women (mean age, 29.4 ± 3.8 years), and 124 primiparous women (mean age, 30.1 ± 4.4 years) participated in this study. Nulliparous non-pregnant women were recruited during health examinations at the university in Nara Prefecture, Japan. Nulliparous pregnant women and primiparous women (until 6 months after delivery) were recruited at an event that was held for pregnant women and mothers in Aichi Prefecture, Japan. The inclusion criteria were women without serious orthopedic disorders or neurological disease. Those with a high-risk pregnancy and a history of pelvic surgery were excluded. Personal characteristics (age, height, and weight), months of pregnancy, and months after delivery history were determined using a questionnaire.

Pelvic measurement

In this study, a PALM palpation meter (Performance Attainment Associates, St Paul, MN) was used to measure pelvic width and tilt angle [12]. Pelvic measurements were performed by trained physical therapists. During the measurement, the participants removed their shoes and stood in an upright position with their feet spread apart and their hands crossed in front of their chest. The anterior width of the pelvis was measured by placement of the caliper tips of the PALM in contact with the bilateral anterior superior iliac spines. The bilateral distance between the anterior superior iliac spines (in cm) was defined as the anterior width of the pelvis. The posterior width of the pelvis was similarly measured as the distance between the posterior superior iliac spines. The pelvic tilt (degree) was measured bilaterally by placement of the caliper tips of the PALM in contact with the ipsilateral anterior and posterior superior iliac spines. The bilateral difference of pelvic tilt was defined as pelvic asymmetry (e.g., if the right pelvic tilt is anterior 3° and the left pelvic tilt is posterior 2°, the pelvic asymmetry is calculated as 5°). The validity estimates of PALM measurements have been shown to be excellent compared with those of radiographic measurements [13]. The PALM is a reliable, valid, and cost-effective clinical tool that has been used in some studies to measure static innominate rotation of the ipsilateral anterior superior iliac spine. Intra-reliability of the PALM has been previously shown to be 0.90 and its inter-test reliability is 0.85 [14,15].

Statistical analysis

All statistical analyses were performed using SPSS version 20.0 (IBM Corp., Armonk, New York). We analyzed the differences of age, height, weight, pelvic asymmetry, anterior pelvic gap, and posterior pelvic gap among the never-pregnant, pregnant, and postpartum groups using one-way analysis of variance (ANOVA) and the Games-Howell post-hoc test with $p < 0.05$ considered to indicate significance. Additionally, we analyzed the differences of the anterior and posterior pelvic gap among the three groups using analysis of covariance (ANCOVA) with the Sidak correction method (alpha = 5%) adjusted by height and weight. Using ANCOVA with the Sidak correction, the analysis was considered significant when $p < 0.017$. In addition, multivariate regression analyses, adjusted for height and weight were performed to determine whether pregnancy and postpartum were associated with pelvic alignment. For this analysis, the pelvic alignment, anterior width of pelvis, and the posterior width of pelvis were dependent variables, whereas the 3 groups (dummy coded with never-pregnant group as the reference) were independent variables. These analyses were adjusted for height and weight. Standard regression values (β) were presented with a significance threshold of 0.05.

Ethical considerations

Written informed consent was obtained from each participant in accordance with the guidelines approved by the Research Ethics Committee of Kio University and the Declaration of Human Rights, Helsinki, 1975. The protocol was approved by the Research Ethics Committee of Kio University (Approval No. H25-47)

Results

The demographic data of the participants are shown in Table 1. Figure 1 shows the measurements of the anterior pelvic width. The anterior width of the pelvis in the pregnant group (25.0 ± 2.3 cm) and post-partum group (24.1 ± 2.3 cm) was wider than the never-pregnant group (23.6 ± 1.9 cm, $p < 0.001$). Figure 2 shows the measurements of the posterior pelvic width. The posterior width of the pregnant group (8.2 ± 2.1 cm) was the narrowest among the three groups (never-pregnant group: 9.1 ± 1.6 cm, postpartum group: 8.6 ± 2.0 cm, $p = 0.008$). Additionally, the anterior width of the pelvis in the pregnant group was significantly wider than the pre-pregnant group ($p = 0.001$) and the posterior width of the pelvis of the pregnant group was also significantly narrower than the never-pregnant group ($p = 0.016$) on ANCOVA.

On one-way ANOVA, pelvic asymmetry of the pregnant and postpartum group were significantly greater than the never-pregnant group (4.2 ± 3.0°, 3.7 ± 3.2°, and 2.8 ± 2.4°, respectively, $p < 0.001$) (Figure 3). Additionally, the Games-Howell post-hoc test indicated that the pelvic asymmetry of the never-pregnant group was significantly smaller than that of the pregnant group ($p = 0.009$) and postpartum group ($p = 0.019$).

To examine the association between pelvic alignment and confounding factors, we carried out a multiple regression analysis

Variables	Total		Never-pregnant		Pregnant		Postpartum		P value
	(n = 346)		(n = 177)		(n = 45)		(n = 124)		
Age (years)	24.3	± 6.3	18.9	±1	29.4	± 3.8§	30.1	±4.4§	< 0.001†
Height (cm)	158	± 5.3	158	±5.3	159	± 5.1	158	±5.4	0.404
Weight (kg)	52.9	± 7.4	52.5	±7.2	57.3	± 7.7§	52.1	±7.2*	< 0.001†
months of pregnancy	-		-		6.6	± 1.8	-		-
months after delivery	-		-		-		4.6	±1.3	-

Table 1: Comparison of characteristics among the three groups.
Note: Values are shown as mean ± SD.
†: P < 0.01
§: Significant difference from the never-pregnant group.
*: Significantly different from the pregnant group.

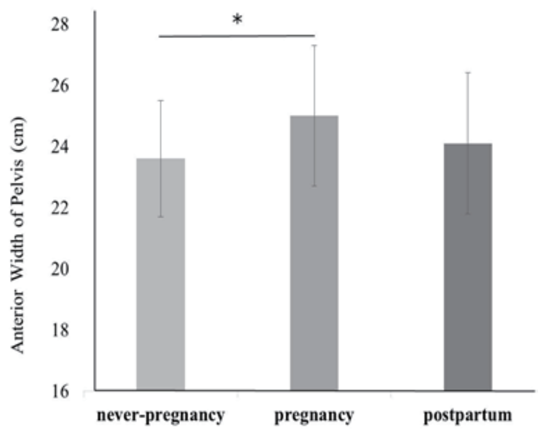

Figure 1: Comparison of the anterior width of the pelvis between the groups by ANCOVA adjusted by height and weight. There were significant differences in the anterior width of the pelvis among the three groups. (P= 0.002) *P < 0.017.

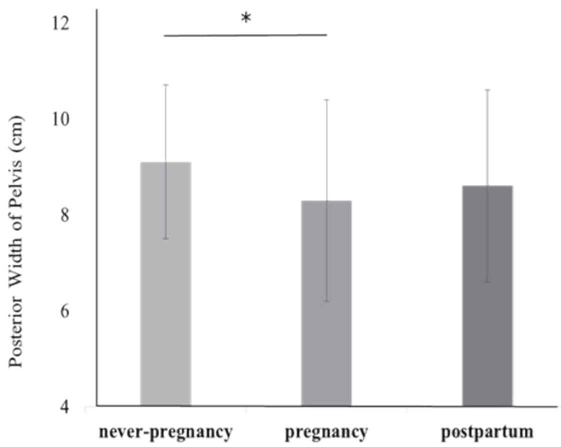

Figure 2: Comparison of the posterior width of the pelvis among the groups by ANCOVA adjusted by height and weight. There were significant differences in the posterior width of the pelvis among the three groups. (P=0.008) *P<0.017.

using pelvic alignment as a dependent variable (Table 2). We found that pregnancy and postpartum were significant and independent determinants of pelvic asymmetry (β = 0.156 and 0.156, p = 0.006 and 0.005, respectively) and the posterior width of pelvis (β = -0.132 and -0.147, p = 0.011 and 0.019, respectively). In addition, pregnancy, postpartum, and weight were also significant and independent determinants of the anterior width of pelvis (β = 0.202, 0.116, and 0.234; p < 0.001, = 0.031, and <0.001, respectively).

Discussion

The results of this study show that pelvic alignment is different among never-pregnant women, pregnant women, and postpartum women. The anterior width of the pelvis of pregnant women was wider than that of never-pregnant women; however, the posterior width of pregnant women was narrower than that of never-pregnant women. The pelvic asymmetry of pregnant women and postpartum women was higher than that of never-pregnant women. Pregnancy and postpartum were positively associated with pelvic asymmetry and the anterior width of pelvis. On the other hand, pregnancy and postpartum were negatively associated with the posterior width of pelvis. Our findings that the width of the pelvis was different between never-pregnant women and pregnant women, and the pelvic asymmetry was different between never-pregnant women and both pregnant and postpartum women but was not different between pregnant women and postpartum women are entirely new.

In this study, we show that the anterior width of the pelvis of pregnant women is wider than that of never-pregnant women but the posterior width of the pelvis of pregnant women is narrower than that of never-pregnant women. Pregnancy and postpartum are significant factors contributing to the anterior and posterior width of the pelvis. During pregnancy, pelvic joints loosen [16]. Previous studies showed that there was a mean increase of 7 mm in vertical stretching and of 3 mm in lateral stretching of the pubic symphysis during pregnancy [17]. Thus, during pregnancy, the interpubic gap is separating [6]. In the loose pelvis, the left-right ilia might move forward with the growth of the fetus. With forward opening of the pelvis, it is possible that the pubic symphysis is extended and the sacroiliac joints are affected with

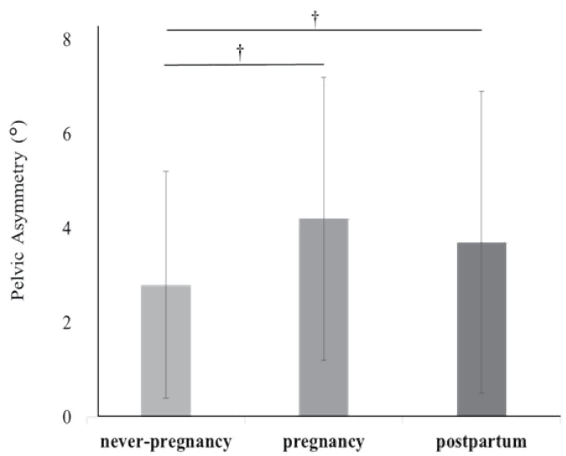

Figure 3: Comparison of the pelvic asymmetry among the groups by ANOVA. There were significant differences in the pelvic asymmetry among the three groups. (P=0.002).

Variables	Pelvic Asymmetry		Anterior Width of the Pelvis		Posterior Width of the Pelvis	
	Standard regression value (β)	P	Standard regression value (β)	P	Standard regression value (β)	P
Never-pregnant	1 [Reference]	-	1 [Reference]	-	1 [Reference]	-
Pregnant	0.156	0.006‡	0.202	<0.001‡	-0.132	0.011†
Postpartum	0.156	0.005‡	0.116	0.031†	-0.147	0.019†
Height	0.112	0.056	-0.061	0.278	0.036	0.536
Weight	-0.037	0.53	0.234	<0.001‡	0.004	0.948

Table 2: Multiple regression analyses for the association of factors with pelvic alignment in the 3 groups
The analyses for pelvic alignment were adjusted for height and weight.
†: P < 0.05; ‡: P< 0.01

stenoses. On the other hand, the anterior and posterior width of the pelvis of postpartum women was not significantly different from never-pregnant women and pregnant women. In a previous study, the pubic symphysis and sacroiliac joints were found to separate during delivery [18], and the interpubic gap of postpartum women was wider than that of nulliparous women [10]. The participants of that study were 2 to 12 days postpartum [10]; however, in this study, the postpartum women were measured 1 to 6 months after delivery. The symphysis pubis and sacroiliac joints return to normal 4 and 12 weeks postpartum [1,18-21]. Therefore, the width of the pelvis of postpartum women might recover shortly after delivery.

Pelvic asymmetry of the pregnant postpartum women was larger than that of never-pregnant women. A previous study reported that during pregnancy, the sacroiliac joints have asymmetric laxity [22], and the pelvic tilt during the third trimester of pregnancy is more anteverted than during the first trimester [11]. In healthy adults, carrying baggage on only one shoulder and cross-legged sitting has an effect on the pelvic tilt [23,24]. Therefore, pelvic asymmetry might become higher as the pregnancy progresses because of asymmetric laxity of the sacroiliac joints and daily habitual asymmetric load carrying, such as placing baggage on only one shoulder, cross-legged sitting, or perhaps due to the fetal position. Pelvic asymmetry of the postpartum group was also larger than that of the never-pregnant group. After delivery, the influence of relaxin continues for 3-5 months [6], suggesting that pelvic laxity might continue after childbirth. In this study, a mean 4.6 months elapsed between delivery and pelvic measurements. Therefore, postpartum women might still have pelvic laxity and pelvic asymmetry.

This study shows that it is possible that the pelvis of pregnant women opens forward. The pubic symphysis might be extended and sacroiliac joints might be affected with stenoses. Pregnant women frequently complain of pubic and sacroiliac pain [16]. Pubic pain might be caused by this extended pubic symphysis and sacroiliac pain could be caused by sacroiliac stenosis. A previous study reported that pelvic alignment is associated with low back pain [25,26]. Low back pain is one of the most common causes of discomfort during pregnancy [27]. It is possible that pelvic asymmetry is a risk factor associated with pregnancy-related low back pain. Additionally, further studies are required to determine the associations between pelvic alignment and pelvic pain and between pelvic alignment and daily habitual asymmetric load carrying, a method for treatment. Results from these studies may help in taking countermeasures against low back pain by involving medical staff and the patient [28].

Limitations

There were several limitations to the current study. First, this study was cross sectional in design and is not a longitudinal observational study. Therefore, we need further research to investigate the issues of casual relationships. Second, the never-pregnant women were recruited from a different setting than the other groups. This is because pregnant and postpartum women were recruited at the event that was targeted at only pregnant women and mothers. Third, we have not measured other factors that may affect pelvic alignment, such as the level of pregnancy-related hormones, muscular strength, physical flexibility, months of pregnancy, and months after delivery.

Conclusion

The current study revealed that the anterior width of the pelvis of pregnant women was wider but the posterior width of the pelvis was narrower than that of never-pregnant women. The pelvic asymmetry of pregnant and postpartum women was larger than that of never-pregnant women. Our study showed that pelvic alignment was different among the three groups. Our results indicate that it is necessary to study pelvic alignment in a longitudinal study and to explore the association between pelvic asymmetry and pregnancy-related pelvic pain. This study provides insight into the necessity of research on the association between anterior and posterior width of the pelvis and pelvic asymmetry and pelvic pain.

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Research Article

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Association between Premenstrual Syndrome and Daily Physical Activity Levels

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Abstract

Objective: The purpose of this study was to investigate the association between premenstrual syndrome (PMS) and daily physical activity.

Methods: Three hundred forty-nine women (18-50 years) were analyzed. We investigated body mass index, PMS symptoms, physical activity level, and some factors related to PMS (age, sleep time, caffeine intake, alcohol intake, smoking status). Participants were grouped according to physical activity level into low, normal, and high physical activity groups. Binominal logistic regression analysis was used to examine the association between PMS and daily physical activity level.

Results: The average physical activity levels of the low, normal and high physical activity groups were 301.4 ± 233.8 kcal, 975.0 ± 187.3 kcal, and 4558.7 ± 3798.5 kcal, respectively. The incidence of PMS was higher in both the low physical activity group (OR=2.45, 95% CI=1.18-5.11) and high physical activity group (OR=2.13, 95% CI=1.01-4.50) than in the normal physical activity group.

Conclusion: PMS rates were higher in women who have either low or high daily physical activity levels than in those with normal physical activity levels. Therefore, women should be advised to avoid inactivity or excessive daily physical activity.

Keywords

Daily life; Premenstrual syndrome; Physical activity; Quality of life; Self-management; Women; Women's healthcare

Introduction

Premenstrual syndrome (PMS) is a common health problem for women of reproductive age. PMS is a collection of psychological, behavioral, and physical symptoms that occur during the late luteal phase of the menstrual cycle and disappear by the onset of menstruation [1]. Up to 80 percent of women report one or more symptoms during the luteal phase of their menstrual cycle, and 20 to 32 percent of premenopausal women report that PMS symptoms interfere with their daily life [2]. The etiologies of PMS are not clearly defined, but it is believed that lifestyle and nutritional factors such as sleeping time, caffeine consumption, alcohol intake, and smoking are associated with PMS [3-5].

For the treatment of PMS, medication (antidepressants, oral contraceptives, vitamin B6, etc.), surgery (removal of ovaries), and alternative non-pharmacological treatments (exercise, dietary measures, cognitive-behavioral therapy, etc.) have been proposed [6-8]. Considering the side effects of drug treatments and surgery, lifestyle modifications such as increasing exercise are recommended [2], and exercise is listed in the first line of a suggested treatment algorithm for PMS [9]. Zeinab Samadi et al. evaluated non-athletic female students and found that 8 weeks of aerobic exercise was effective in reducing PMS symptoms [10]. Physical activity programs that showed a positive effect for PMS and menstrual dysfunction included treadmill training, Baduanjin exercise, and yoga methods [11-13].

While these exercise programs may be effective at reducing PMS symptoms, starting a new exercise program is difficult for women, especially women of reproductive age who often have many tasks, including business work, housework, and/or academic work. Considering the burden of premenstrual symptoms that appear repeatedly in every menstrual cycle, effective measures are needed to prevent or reduce these problems. Thus, guidelines that suggest the appropriate amount of physical activity in daily life for reducing the symptoms of PMS would be beneficial. Therefore, the purpose of this study was to investigate association between PMS and daily physical activity.

Materials and Methods

Ethical considerations

Written informed consent was obtained from each participant in accordance with the guidelines approved by the Kyoto University Graduate School of Medicine and the Declaration of Human Rights, Helsinki, 1975. The protocol was approved by the Ethics Committee of Kyoto University Graduate School of Medicine (protocol approval E-2110).

Participants

In total, 372 women in Japan between the ages of 18 and 50 years were recruited as a volunteer from May 2013 to April 2014 by the advertisement from the research practitioners. Eligibility was determined by questionnaire and interview, and 27 women with current medical, psychiatric, or gynecological problems, including pregnancies, amenorrhea, or current treatment of menstruation-associated symptoms, were excluded. Thus, 349 participants were finally included in the analysis.

Questionnaire of basic information and factors related to PMS

Data obtained by original questionnaire included age, height, weight, daily sleep time, caffeine intake, alcohol intake, whether the participant smoked or not, presence of PMS symptoms and physical activity level. Caffeine intake was assessed with the question "How many cups of coffee, tea or green tea do you usually drink in a week?". Alcohol intake was assessed with the question "Do you usually drink alcohol?". Body mass index (BMI) was calculated using self-reported data on height and weight.

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Questionnaire of premenstrual syndrome symptoms

A questionnaire was constructed based on the diagnostic criteria for PMS outlined by the American College of Obstetricians and Gynecologists (ACOG, 2005) including six affective and four somatic symptoms: depression, angry outbursts, irritability, anxiety, confusion, social withdrawal, breast tenderness, abdominal bloating, headache and swelling of the extremities. Premenstrual syndrome can be diagnosed if the patient reports at least one of the symptoms during the 5 days before menses in each of the three prior menstrual cycles. In addition, PMS patients suffer from identifiable dysfunction in social or economic performance. Hence, for each symptom the participants were asked, "Did you feel the abnormality in the physical and/or emotional conditions for five days before menses, and was that repeated for more than three months in the past? Did the symptoms impair your daily life?". According to the diagnostic criteria by ACOG, clinicians had to confirm that the symptoms occur repeatedly during two cycles in prospective recording. However, we did not collect prospective information because our purpose in this study was to explore the relation between premenstrual symptoms and daily physical activity, rather than to make a diagnosis of PMS.

Questionnaire of daily physical activity

The International Physical Activity Questionnaire-Short Form (IPAQ-SF) was used to assess daily physical activity [14,15]. First, using the IPAQ-SF, we recorded the average daily physical activity in one standard week in terms of metabolic equivalent (MET) units. A MET is the ratio of the rate of energy expended during an activity with the rate of energy expended at rest. Next, to investigate the physical activity in consideration of individual somatotype, we calculated physical activity in kcal using the equation:

Physical activity (kcal) =1.05 × amount of physical activity (MET) × time of physical activity (hours) × weight (kg)

Statistical analysis

Prior to analysis, the participants were divided into 3 groups according to their daily physical activity levels, i.e., into tertiles. Differences in the age, sleep time, and caffeine consumption among the 3 groups were examined using the analysis of variance (ANOVA). When a significant effect was found, differences were determined with the Tukey-Kramer's post-hoc test. Differences in alcohol intake and smoking status among the 3 groups were evaluated using the chi-square test. In addition, multivariate logistic regression analyses adjusted for age and other factors related to PMS (sleeping time, caffeine consumption, and alcohol intake and smoking) to determine whether the PMS symptoms were associated with physical activity level. For this analysis, the presence of PMS symptoms was considered as the dependent variable, whereas the physical activity level—divided into 3 groups (which were dummy-coded using normal physical activity as the reference group)—was used as the independent variable. For the independent variables that remained in the final step of the regression analysis, odds ratios (ORs) with 95% confidence intervals (CI) were determined. Statistical analyses were carried out using SPSS version 20.0 (SPSS, Chicago, Ill., USA), with a significance threshold of 0.05.

Results

The demographic data of the participants stratified into 3 groups according to daily physical activity levels are shown in Table 1. The physical activity level of each group was 301.4 ± 233.8 kcal in the low physical activity group, 975.0 ± 187.3 kcal in the normal physical activity group, and 4558.7 ± 3798.5 kcal in the high physical activity group. ANOVA showed that there were significant differences in age and caffeine consumption among the 3 groups (Table 1). In the chi-square test, there were significant differences in alcohol intake and smoking among the groups (Table 1).

Among the all participants, a total of 73 (20.9 %) participants had PMS symptoms, and the presence of PMS symptoms for each group is shown in Figure 1. In the multivariate logistic regression analysis, after adjustment for age, sleeping time, caffeine consumption, alcohol intake, and smoking, using normal physical activity as the reference, participants with low physical activity level (OR: 2.45, 95% CI: 1.18-5.11, p=0.016) and those with high physical activity were significantly more likely to have PMS (OR: 2.13, 95% CI: 1.01-4.50, p=0.047) (Table 2).

Discussion

In this study, we considered the relationship between PMS and daily physical activity level. We found significant differences in PMS prevalence among groups with different physical activity levels. The prevalence of PMS symptoms of both the low and high physical activity groups is higher than that of the normal physical activity group for the participants in this study, and this difference was still statistically significant after adjustment for other factors related to PMS. Since the industrial revolution, the development of new technologies has enabled people to reduce the amount of physical labor needed to accomplish many tasks in their daily lives. Inactivity tends to rise with age, and is higher in women than in men [16]. On the other hand, female participation in athletic activity or the physical exercise with aesthetic or addictive purposes with distorted body image has increased in recent years [17,18]. Our findings show that extremely high or low levels of daily physical activity may be a risk factor of PMS symptoms.

Table 1: Demographic differences according to physical activity levels.

	Physical activity level					
	Total (n=349)	Low (n=116)	Normal (n=117)	High (n=116)	*p*-value	Post-hoc
Physical activity (kcal)[a]	1942.2 ± 2875.6	301.4 ± 233.8	975.0 ± 187.3	4558.7 ± 3798.5	<0.001	Low, Normal<High
Age (years)[a]	24.1 ± 9.1	26.2 ± 9.8	21.0 ± 6.1	25.2 ± 10.2	<0.001	Normal<Low, High
Body mass index (kg/m^2)[a]	20.7 ± 2.9	20.2 ± 2.4	20.2 ± 2.3	21.7 ± 3.5	<0.001	Low, Normal<High
Sleeping time (min)[a]	362.4 ± 68.9	358.0 ± 57.2	366.7 ± 74.5	362.3 ± 73.8	0.633	
Caffeine consumption (cup)[a]	17.1 ± 15.5	22.1 ± 16.8	16.1 ± 11.5	13.1 ± 16.3	<0.001	Normal, High<Low
Alcohol intake (n)	107 (30.7%)	60 (51.7%)	40 (34.2%)	7 (6.0%)	<0.001	High<Normal<Low
Smoking (n)	34 (9.7%)	26 (22.4%)	5 (4.3%)	3 (2.6%)	<0.001	Normal, High<Low

[a]Values are shown as mean ± standard deviation.

Table 2: Relationship between PMS and physical activity.

	PMS	
Physical activity	**OR (95% CI)**	***p***
normal	1 [Reference]	-
low	2.45 (1.18–5.11)	0.016
high	2.13 (1.01–4.50)	0.047

Note: The analyses were adjusted for age, sleeping time, caffeine consumption, alcohol intake and smoking status.

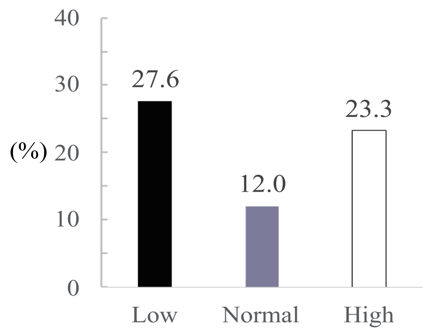

Figure 1: The presence of PMS symptoms of each group.

Moderate physical activity has the effect of improving some of the symptoms of PMS, including mood disturbance, fatigue, cognitive dysfunction, and bloating that typically is experienced by women who suffer from PMS [19]. In addition, the repetitive contraction in aerobic exercise aids venous blood to return and helps prevent or reduce back pain and discomfort in the pelvis and abdomen, symptoms of PMS, by decreasing the local concentration of prostaglandins and other inflammatory substances [20]. The lack of these effects in women with low physical activity may explain the increased prevalence of PMS in women with low levels of physical activity compared to those with normal physical activity.

In contrast, the stress or intensity of excessive physical activity, or some combination of these factors, may influence the mind and body of women and contribute to menstruation-related disorders [21]. Takeda et al. suggested that female athletes have a high prevalence of PMS symptoms because of an intense work load and severe stress [22]. Moreover, it may be that fatigue is increased in women who performed high levels of activities. A relationship between stress level and PMS has been reported [23], so fatigue and stress caused by excessive activity is likely to have contributed to the onset of PMS in the participants of this study. These are among the possible reasons why women who have high level of daily physical activity had a higher prevalence of PMS symptoms than the normal physical activity group in this study.

There were several limitations to the present study. First, we investigated only the amount of daily physical activity. To assess the daily activity level more accurately, it would be necessary to measure the specific activity, such as sports, work, and housework. It also would be desirable to investigate fatigue and stress caused by the activities. Second, we collected the data such as smoking and caffeine consumption by original questionnaire for convenient screening not by standard instruments. Finally, this was a cross-sectional, not a longitudinal observational study. Therefore, we would need further research to reveal whether changing physical activity level would influence PMS symptoms in the same participants. Despite these limitations, the findings from this study suggest the importance of physical activity in the daily life of reproductive-aged women.

Although physical exercise has been recommended as one of the non-drug therapies for PMS, the evidence for this intervention is not clear yet [24]. According to our data, exercise should not be recommended blindly to women who suffer from PMS. In the future, it will be necessary to explore specific mechanisms of physical activity for improving PMS symptoms, to avoid incorrect guidance. In addition, in this study, we investigated the daily physical activity level including daily work, rather than a specific exercise. These findings indicate that, in the clinical practice of women's healthcare, it is useful and reasonable to assess not only premenstrual symptoms but also the daily physical activity and the accompanying stress in order to provide appropriate guidance and medication for the improvement of PMS.

Conclusion

In the current study, the association between premenstrual syndrome and daily physical activity levels was investigated and it was revealed that PMS rates were higher in women who have either low or high daily physical activity levels than in those with normal physical activity levels. The results indicate that daily physical activity level might be related to PMS, and women should be advised to avoid inactivity or excessive daily physical activity.

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Research Article

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Association of Lumbopelvic Pain with Pelvic Alignment and Gait Pattern during Pregnancy

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Abstract

Study background: Management of lumbopelvic pain (LPP) during pregnancy is important and the anatomical and movement aspects may be related to LPP. This study aimed to investigate the association of LPP with pelvic alignment and gait pattern during pregnancy.

Methods: Fifty-seven pregnant women were categorized into either the LPP or non-LPP (NLPP) group. Anterior pelvic tilt and bilateral difference in pelvic tilt as pelvic asymmetry were measured. An inertial measurement unit was attached at the participants' L3 spinous process to measure 3-axes acceleration during gait. The degrees of movement symmetry, gait variability, and trunk movement were expressed as the autocorrelation peak (AC), coefficient of variance, and root mean square (RMS), respectively. An independent t-test was used to investigate differences in pelvic alignment and gait parameters between the groups. Multivariate stepwise logistic regression analysis was used to identify parameters that affected LPP. Additionally, multivariate linear regression analyses were performed to determine the parameters affected by LPP. Each significant parameter (from the previous analysis) was included as a dependent variable. Meanwhile, the presence or absence of LPP, BMI, and pregnancy months were included as explanatory variables.

Results: In the LPP group, pelvic asymmetry was significantly higher, and the AC and RMS were significantly lower than that in the NLPP group. In the multivariate analysis, pelvic asymmetry and AC significantly affected LPP, while LPP significantly affected pelvic asymmetry and RMS.

Conclusion: Pelvic asymmetry and movement asymmetry during gait affect LPP, while LPP affect pelvic asymmetry and trunk movement during gait. Therefore, evaluating both of the pelvic alignment and gait pattern especially focusing on asymmetry is important for management LPP during pregnancy.

Keywords

Asymmetry; Gait analysis; Lumbopelvic pain; Posture; Pregnancy

Introduction

Lumbopelvic pain (LPP) is common discomfort experienced by women during and after pregnancy with approximately 45% of pregnant women and 25% of postpartum women experience this pain [1]. Unfortunately, pregnancy-related LPP often adversely influences these women's activities of daily living, such as cleaning, working outside the home, and even sleeping [1,2]. Thus, LPP is known to lower the quality of life for many women during and after pregnancy [3]. Therefore, the factors that are related to LPP during pregnancy should be identified and, if possible, addressed to allow for a more comfortable pregnancy.

The main factors that are related to LPP during pregnancy are thought to be increased joint laxity such as sacroiliac joint (due to pregnancy-related hormones) and pelvic anteversion (due to pregnancy-related abdominal swelling) [4,5]. Moreover, various other anatomical and physiological changes also occur in women's bodies during pregnancy. For example, one previous study has reported a differing degree of pelvic anteversion in the right and left sides during pregnancy [6]. Therefore, the investigation of relationship between physiological aspects especially focusing on pelvic positioning and LPP during pregnancy is needed.

In addition to physiological and posture aspects, movement patterns during daily activity are typically thought to be strongly associated with low back pain [7]. On this point, changes in movement patterns during daily activities (such as gait pattern, step and stride length, stance phase, and joint motion during gait) have been observed as pregnancy progresses [8,9]. The changes in the gait pattern mechanics are characterized by changes in the woman's physiological shape and dimensions, particularly in the trunk [10]. In addition, these movements are thought to be related to lower back pain, especially those that are accompanied by flexure and rotation of the trunk, such as sitting and active bending [11]. Similarly, pregnancy-related LPP often adversely influences the daily activities, such as carrying, sitting, and walking [12]. Furthermore, Wu et al. have indicated that gait speed was significantly reduced in postpartum women with pregnancy-related pelvic pain, compared to that in healthy women [13]. Therefore, changes in gait pattern during pregnancy may also be related to LPP during pregnancy.

Therefore, the static and dynamic aspects and LPP may be mutually related during pregnancy. However, the relationship between LPP and both of these static and dynamic aspects in the same subjects has not been established for pregnant women. Therefore, this study aimed to investigate the association of LPP with static pelvic alignment and gait pattern during pregnancy.

Materials and Methods

Participants

Pregnant women were recruited at an event that was held for pregnant women and mothers in Aichi Prefecture, Japan, during March 2013. Among the attendees, 57 women who were between the third and tenth month of pregnancy, and who had no history of lower back, foot, ankle, knee, musculoskeletal, and neuromuscular trauma or disease, were included in this study. The inclusion criterion was a pregnancy without serious orthopedic disorders or neurological diseases, and participants with external injuries that affect the gait analysis were excluded for recruitment. The women who met the inclusion criterion in the attendees of the event were investigated and there was no one excluded after the recruitment of this study.

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Questionnaire

Personal characteristics (age, height, and mass), month of pregnancy, and the presence or absence of LPP were determined using a questionnaire.

The presence or absence of LPP was evaluated using a picture of the human body (Figure 1) and the question "Do you currently have any pain in your lower back, sacroiliac joint, or around your pubic bone or have you had any pain there during your pregnancy? Please refer to the picture for these pain locations." If there was anything participants can't understand about the question, the researcher of this study (midwife or physical therapist) answered. Based on the answers of participants, they were categorized into LPP and non-LPP (NLPP) groups according to the presence or absence of LPP.

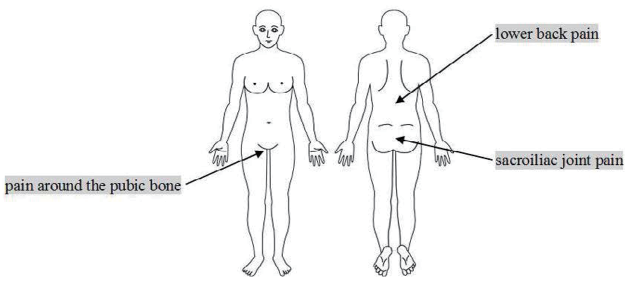

Figure 1: The original picture used to evaluate the presence/absence of lumbopelvic pain.

Pelvic alignment

Pelvic alignment was measured using a palpation meter (Performance Attainment Associates, St. Paul, MN, USA). The anterior pelvic tilt was measured bilaterally by placing the caliper tips of the palpation meter in contact with the ipsilateral anterior and posterior superior iliac spines (Figure 2). This method is valid, reliable, and cost-effective for calculating any discrepancy between the patient's landmarks [14]. Before the measurement, the researchers (two physical therapists) learned use method of the palpation meter and practiced repeatedly. In order to verify accuracy, the measurers measured pelvic alignment of a woman separately by the above method. The verification procedure was repeated twice, two weeks apart. As the result, the measurement procedure showed acceptable intra and inter-rater reliability with Intraclass Correlation Coefficients (ICC 1.1) of 0.998 (95% CI 0.995-0.999) and 0.998 (95%CI 0.992-1.000) for the anterior pelvic tilt in this study. During the pelvic alignment measurements, the participants took off their shoes and stood with hands crossed in front of their chest. Left and right anterior pelvic sagittal tiltings were measured in degrees. The mean left and right pelvic tilt degrees, and the bilateral difference in pelvic tilt were defined as anterior pelvic tilt and pelvic asymmetry, respectively.

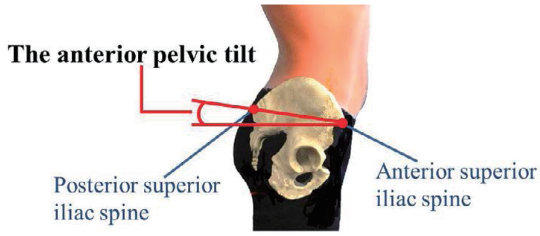

Figure 2: The measurement points for the pelvic alignment.

Gait procedure and apparatus

All participants were evaluated using a smooth, horizontal, 14-m walkway. Gait was measured in a 10-m long middle section of the walkway, which was created by applying 2 lines (2 m from each end of the walkway) to allow for acceleration and deceleration. Participants performed the tests at their preferred speeds and while wearing shoes that did not mostly influence their gait.

The acceleration and angular velocity of the participant's trunk were measured during the gait testing using a triaxial accelerometer (MVP-RF-8, MicroStone Co., Nagano, Japan). The sensor unit contained a tri-axial angular rate gyroscope and a linear accelerometer. Based on the method used by Moe-Nilssen and Helbostad [15], the sensor units were attached to a fixed belt at the level of the L3 spinous process, which is used to assess motion of the trunk during gait. However, we also considered it likely that the accelerometers attached to the body might experience various inclination states, due to the body's curvature. To correct for any potential effects of these inclinations, we calibrated the accelerometer before each gait trial to take into account the static gravity component. The signals were sampled at a frequency of 200/s and were wirelessly transferred to a personal computer via a Bluetooth. To identify the walk cycle, a pressure sensor (FlexiForce, Nitta Co., Osaka, Japan) was attached to the participant's heel, and this sensor was synchronized with the accelerometer. The heel contact event was defined as the time when the sensor's voltage increased. The participants were timed as they walked over the 10-m portion of the walkway, and their gait speed was expressed in meters per second.

Data analysis

Signal processing was performed using MATLAB (The MathWorks Co., Release 2013b, Tokyo, Japan). Based on the method used by Nishiguchi, et al. [16], the autocorrelation peak (AC), coefficient of variance (CV), and root mean square (RMS) of the acceleration peak intervals were calculated using trunk acceleration data from 10 strides that were performed while walking in a steady state. Autocorrelation is useful for finding repeating patterns in a signal, and symmetry is a fundamental property of autocorrelation, therefore a higher AC value indicates a greater degree of symmetry during movement. The CV indicates the degree of gait variability, which was defined as the variability in the time that elapsed between the heel contacts for two consecutive footfalls. A higher RMS value indicated greater movement of the trunk. RMS is affected by gait speed (it is proportional to the square of gait speed), therefore we adjusted the RMS by dividing it by the square of the gait speed [17].

Ethical considerations

Written informed consent was obtained from each participant, in accordance with the guidelines approved by the Research Ethics Committee and the Declaration of Human Rights, Helsinki, 1975. The study's protocol was approved by the Research Ethics Committee of Kio University (Approval No. H25-47).

Statistical analysis

Differences in age, mass, height, and month of pregnancy between the LPP and NLPP groups were evaluated using the independent *t*-test. We also initially used an independent *t*-test to evaluate the differences in the pelvic tilt, pelvic asymmetry, and each gait parameter between the LPP and NLPP groups. After this initial analysis, a multivariate step-wise logistic regression analysis was used to identify which parameters affected LPP, from among the factors that were statistically different when the two groups were compared. Finally, we performed multivariate linear regression analyses to determine which parameter was affected by LPP; each of these parameters was included as a dependent variable, and the presence or absence of LPP, body mass index, and month of pregnancy were used as explanatory variables. Statistical analyses were performed using SPSS version 20.0 (SPSS, Chicago, IL, USA), with a significance threshold set at 0.05.

Results

The demographic data of the LPP and NLPP groups are shown in Table 1. The prevalence of LPP was 75.4% (LPP group; n=43, NLPP group; n=14), although no significant differences were observed between the groups regarding age, height, mass, and month of pregnancy (Table 1). The pelvic asymmetry of the LPP group was significantly greater than that in the NLPP group (4.91 [SD 3.41]° *vs.* 2.07 [SD 2.06]°, respectively; p=0.001), although no significant differences were observed in the anterior pelvic tilt (2.59 [SD 3.94]° *vs.* 2.75[SD 5.40]°, respectively; p=0.907) (Figure 3). Among the gait parameters, the AC and RMS of the LPP group were significantly lower than those in the NLPP group (AC: 0.64 [SD 0.16] *vs.* 0.74 [SD 0.08], respectively; p = 0.004, RMS: 2.77 [SD 0.57] *vs.* 3.15 [SD 0.49]; p=0.027), although no significant difference was observed in the CV (0.052 [SD 0.036] *vs.* 0.050 [SD 0.028]; p=0.827) (Figure 3). In the multivariate step-wise logistic regression analysis, pelvic asymmetry (odds ratio and 95% confidence interval: 1.499 [1.069–2.101]) and AC (0.001 [0.000–0.911]) significantly affected LPP (Table 2). In contrast, in the multivariate linear regression analysis, LPP significantly affected pelvic asymmetry (β / p-value: 3.014/0.004) and RMS (–0.382/0.037) (Table 3).

Discussion

The current study investigated the association of LPP with both of static and dynamic aspects during pregnancy. Based on the results, higher pelvic asymmetry and lower AC had affected LPP during pregnancy. A previous study among adults has reported that static pelvic asymmetry is associated with lower back pain [18]. Besides, in the study of pregnant women, Damen et al. reported that pelvic pain is associated with asymmetric laxity of the sacroiliac joints [19], and Sipko, et al. observed asymmetric of pelvis alignment and irritation of pelvic and lumbar ligaments [20]. These results suggest that changes in pelvic alignment can easily occur during pregnancy and the resulting pelvic malalignment is related to LPP. We observed a similar result among pregnant women in this study. In addition, the lower AC of the LPP group indicated that pregnant women with LPP exhibited greater asymmetry during their gait. These results were similar to Selles, et al. who observed greater asymmetry among patients with lower back pain (compared to a control group) when they examined the phase-relations of the body's left and right sides during gait [21]. It is possible that the asymmetry change in the static aspect occurs easily during pregnancy, due to the loosening action of pregnancy-related hormone on the body joints. Moreover, we observed motion asymmetry during gait in the participants of this study, as well as static pelvic asymmetry in pregnant women with LPP. Therefore, the static pelvic asymmetry might be related to asymmetry of the dynamic gait pattern. For example, it has been proposed that pelvic asymmetry alters the body mechanics, placing strain on various body segments, which subsequently contributes to musculoskeletal pain [22]. Therefore, our results indicate that both the static and dynamic aspects asymmetry might affect LPP during pregnancy.

In addition, our results indicate that LPP had an effect on lower RMS and higher pelvic asymmetry during pregnancy. The lower RMS indicated that the pregnant women with LPP moved their trunk less during gait, compared to the women in the NLPP group. Similarly, Al-Eisa, et al. have observed that pain-free people exhibit a broader range of movement in the lower thoracic region, compared to people with lower back pain [11]. Wu, et al. have also reported that pregnancy-related pelvic girdle pain decreased the rotation between the pelvis and lumbar segment, the lumbar segment and the thorax, and the pelvis and the thorax, especially at higher velocities [23]. Similarly, we observed that pregnant women with LPP tended to avoid excessive movement of the trunk during gait to reduce the pain they experienced. Furthermore, several study have demonstrated that the maximum gait speed is lower for people with pelvic girdle or lower back pain, compared to that for healthy people [13,24]. Therefore, pregnant women are compelled to control their trunk movement during gait (due to pain), which deteriorates their gait function. Moreover, we observed that LPP resulted in greater static pelvic alignment asymmetry among pregnant women. Thus, pelvic asymmetry appears to cause LPP, and untreated LPP can result in exacerbated chronic asymmetry.

Our results indicate that both the static and dynamic aspects mutually related to LPP during pregnancy. Thus, it is possible that these associations might create a vicious cycle, and treatment or prevention of LPP during pregnancy is needed to break this cycle. However, treatment via medication or surgery should be avoided during pregnancy, given the potential adverse effects on the mother and fetus [25]. Therefore, the factors that contribute to LPP must be identified, as these might be safe to treat. Our results indicate that greater pelvic and gait pattern asymmetry might affect LPP during pregnancy. Therefore, it is important to evaluate both the static and dynamic aspects of the pelvic region to prevent or treat LPP during pregnancy. Furthermore, treatment strategies that focus on the asymmetry of these aspects might be effective in resolving the LPP during pregnancy.

Table 1: Demographic differences according to the presence of lumbopelvic pain.

		Presence of LPP†		
	Total (n = 57)	**LPP† group (n = 43)**	**NLPP‡ group (n = 14)**	***p*-value**
Age (years)	29.9 [SD 3.7]	29.8 [SD 3.8]	30.2 [SD 3.7]	0.733
Height (cm)	158.4 [SD 5.5]	158.2 [SD 5.6]	158.9 [SD 5.3]	0.687
Mass (kg)	57.1 [SD 7.9]	57.9 [SD 8.5]	54.7 [SD 4.9]	0.189
Month of pregnancy (month)	6.7 [SD 1.8]	6.7 [SD 1.5]	6.8 [SD 2.3]	0.837

Note: Values are shown as mean [standard deviation (SD)].

† LPP: lumbopelvic pain, ‡ NLPP: non-lumbopelvic pain.

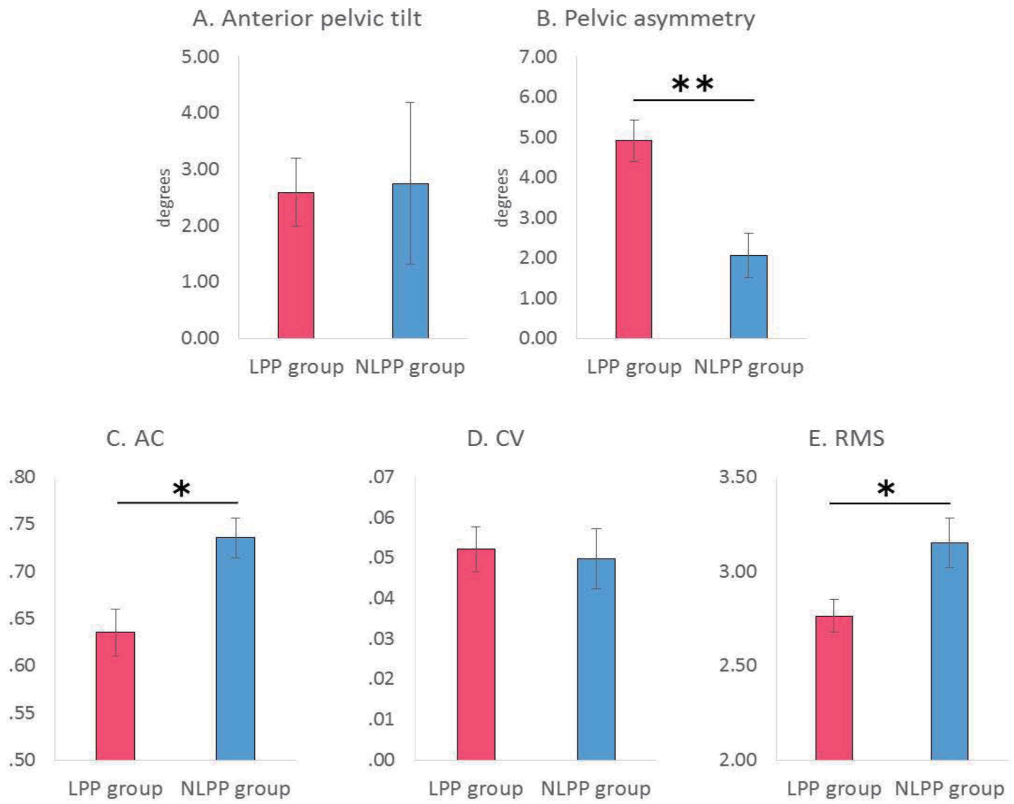

Figure 3: Clinical characteristics and statistical parameters according to the presence or absence of lumbopelvic pain.

Note: [Memo] LPP: lumbopelvic pain, NLPP: non-lumbopelvic pain, AC: autocorrelation peak, CV: coefficient of variance, RMS: root mean square.

*p<0.05, **p<0.01

Table 2: Parameters associated with lumbopelvic pain in a multiple stepwise regression analysis.

Parameter	Odds ratio	95% CI †	*p*-value
Pelvic asymmetry	1.499	1.069–2.101	0.019*
AC ‡	0.001	0.000–0.911	0.047*
RMS §	0.286	0.074–1.095	0.068

Note: **p*<0.05; † CI: confidence interval, ‡ AC: autocorrelation peak, § RMS: root mean square.

Table 3: Parameters associated with pelvic asymmetry, the autocorrelation peak, and root mean square in a multiple linear regression analysis.

	Independent variable	Regression coefficient	Standard regression coefficient	*p*-value	R^2 value
Pelvic asymmetry					0.173
	LPP †	3.014	0.997	0.004*	
	BMI ‡	–0.092	0.166	0.582	
	Month of pregnancy	0.399	0.257	0.126	
AC §					0.109
	LPP †	–0.093	0.047	0.052	
	BMI ‡	–0.004	0.008	0.609	
	Month of pregnancy	0.015	0.012	0.213	
RMS ‖					0.089
	LPP †	–0.382	0.179	0.037*	
	BMI ‡	–0.002	0.030	0.953	
	Month of pregnancy	0.019	0.046	0.682	

Note: † LPP: lumbopelvic pain, ‡ BMI: body mass index, § AC: autocorrelation peak, ‖ RMS: root mean square.

**p*<0.05

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There were several limitations in the current study. First, this study used a cross-sectional design, rather than a longitudinal observational design. Therefore, further research is needed to investigate the causality of the relationships that we observed. Second, we investigated the presence of LPP using a self-reported questionnaire, rather than via an orthopedic diagnosis, and we classified the participants according to the presence of pain, rather than the extent of the pain. Thus, detailed pain data were not available, and the prevalence of LPP in this study was higher than that reported in a previous study [3]. However, we captured the features of static and dynamic aliment that were related to LPP via the self-assessed pain data. Third, we did not evaluate other factors that may affect pelvic asymmetry and gait strategy, such as the level of pregnancy-related hormones, muscular strength, or physical flexibility. Therefore, this is a pilot study suggesting association of LPP with static pelvic alignment and dynamic gait pattern during pregnancy that warrants further more detailed investigations. However, despite these limitations, the findings of the present study may encourage measurement of static and dynamic pelvic alignment, which may help to cure LPP.

In the current study, the association of LPP with static and dynamic aspects of pregnancy was investigated and it was revealed that pelvic asymmetry and lower back movement during gait were related to LPP during pregnancy. The results indicate that greater pelvic and lower back movement asymmetry might affect LPP during pregnancy. Meanwhile, LPP might affect movement of the trunk during gait and pelvic asymmetry.

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