

# リハビリテーション科医が読み解くポリオの現在

- 全国ポリオ会連絡会のアンケート結果より -

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# 日本リハビリテーション医学会 COI 開示

筆頭発表者名：蜂須賀 明子

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。



# わが国のポリオの現在 - 患者会アンケート2022年 -



全国ポリオ会連絡会HP <http://www.zenkokupolio.com/>



## アンケート結果のお知らせ

全国ポリオ会連絡会運営委員一同

2022年3月から6月にかけて、830通のアンケート用紙を、全国ポリオ会連絡会に所属する各地の会員に、送付しました。なんと598人の方からご回答をいただきました。回収率72%。本当にありがとうございます。その結果をお知らせいたします。

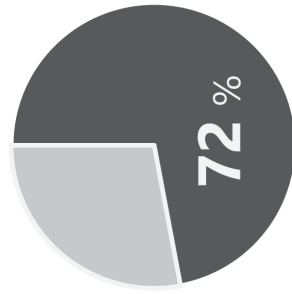
今回のアンケートの主目的は、どれくらいの方が、ポストポリオを発症しているか。さらに、四肢のどの部分に衰えているかを知るためでした。というのも、何らかの衰えを口にする人は増えていて、もともと麻痺のあった部位の衰えなら、皆さん「仕方ない」となり、ある程度諦めもつくのですが、元気だと思っていた部位に衰えが来ると、不安になり、つらく思う人が多かったからです。電話等でその不安を聞くたびに、どのくらいの方が、もともと麻痺がなかったところに衰えを感じているか、知ることができれば、少なくとも「自分だけではないのだ」という安心感だけには得られると考えました。



# アンケート概要

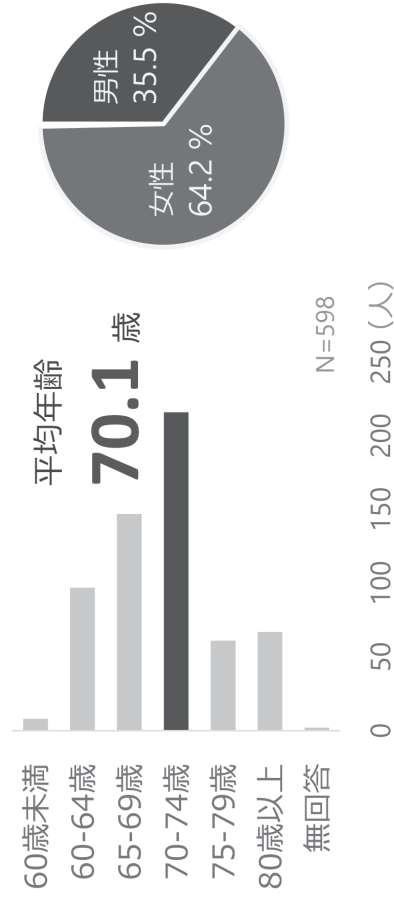
## ■ 調査方法

2022年3月～6月  
会員830名へアンケート送付  
うち598名より回答



アンケート回答率

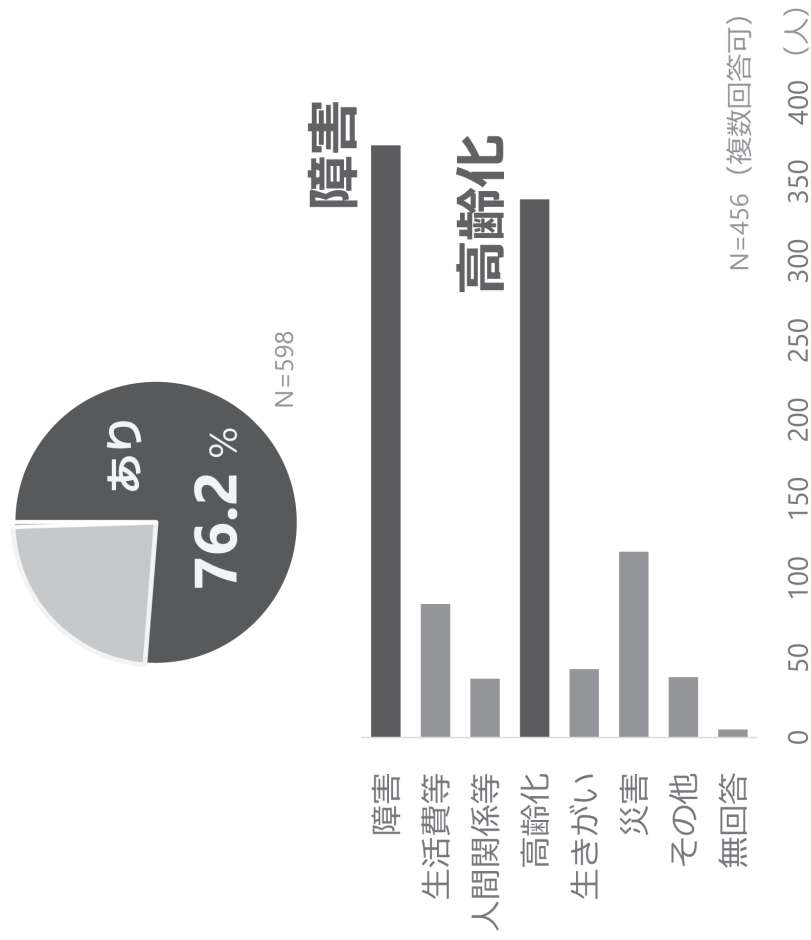
## ■ 性別, 年齢



- 1 基本的な事について
- 2 ポリオ発症時の状況と現状について
  - 1) ポリオの発症と障害部位
  - 2) 障害者手帳
  - 3) 障害年金
- 3 ポストポリオについて
  - 1) 症状が重くなった部位
  - 2) ポリオと診断されている方の特徴
  - 3) ポストポリオと診断されていない方の特徴
  - 4) 通院と在宅リハビリ
- 4 下肢の障害について
- 5 上肢の障害について
- 6 体幹の障害について
- 7 呼吸・嚥下障害について
  - 1) 呼吸機能
  - 2) 嚥下機能
- 8 その他の身体状態について
  - 1) 一般
  - 2) 骨折
  - 3) 疼痛
- 9 車椅子について
- 10 自家用車について
- 11 介護保険と障害福祉サービスの利用について
  - 1) 介護保険サービス
  - 2) 障害福祉サービス
- 12 全国ポリオ会連絡会の活動について

# 1 基本的な事について

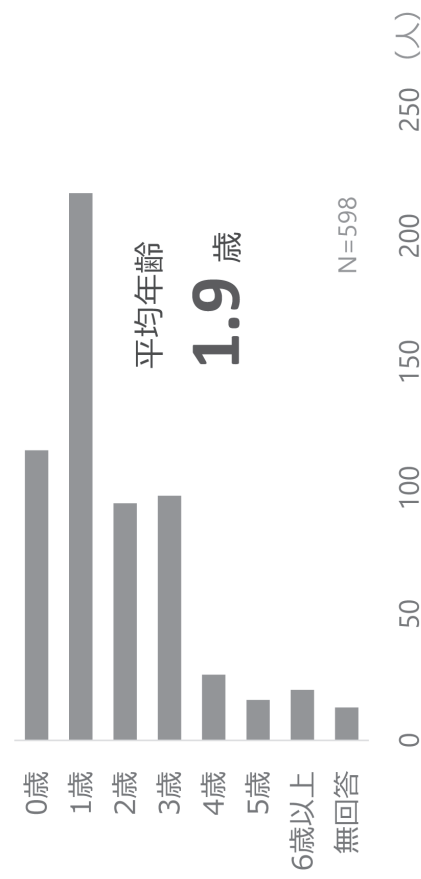
## ■ 生活面等での不安



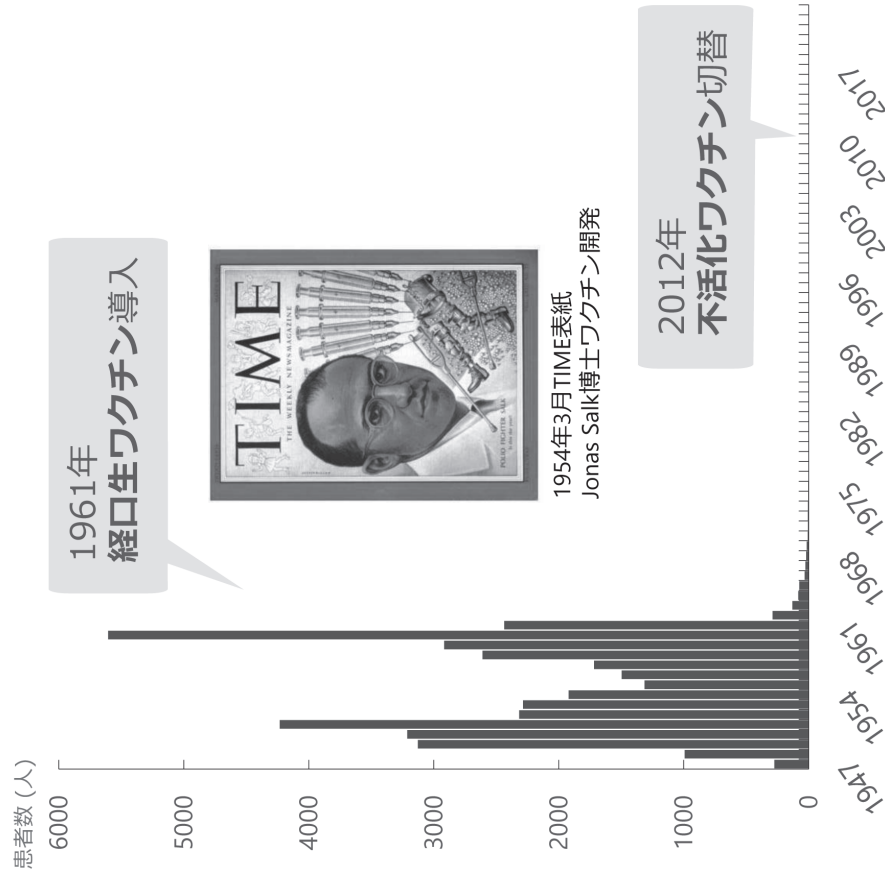
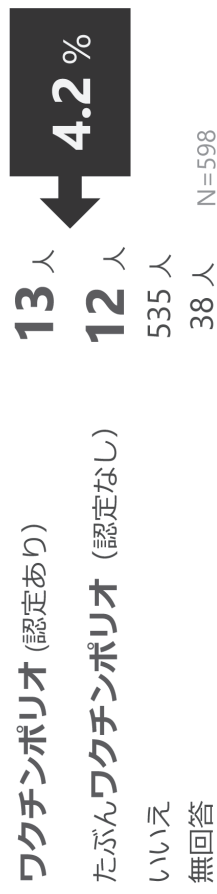
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## 2 ポリオ発症時の状況と現状について

### ■ ポリオの発症時期



### ■ ワクチンポリオか否か

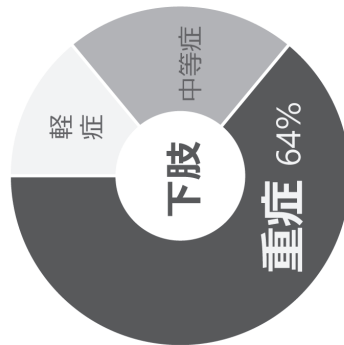
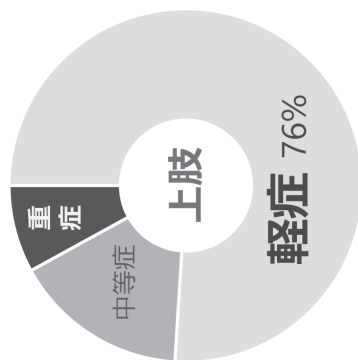


TIME <https://content.time.com/time/magazine/0,9263,7601540329,00.html>

# ポリオの臨床像

## ■ ポリオの臨床重症度 @ UOEH

n=43人、各86肢



NRH肢体別重症度分類  
 軽 症 : NRH I, NRH II  
 中 等 症 : NRH III  
 重 症 : NRH IV, NRH V

ポリオウイルス罹患  
脊髄前角細胞障害

麻痺の回復・固定

重度麻痺



学童期



学生期

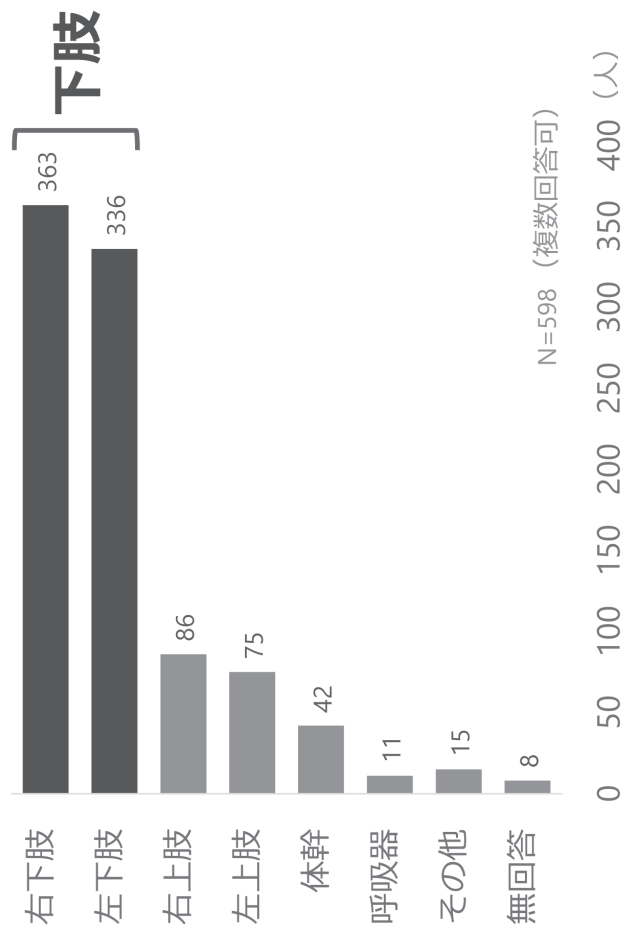


社会人

定年

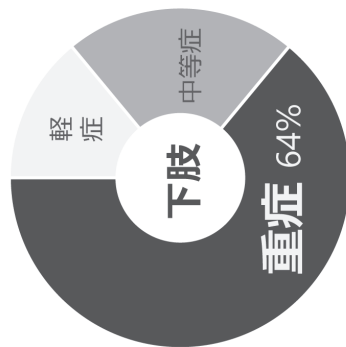
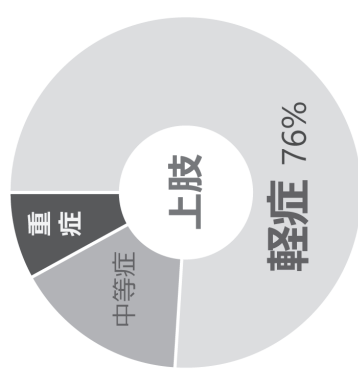
# ポリオは下肢の麻痺が多い

## ■ 最初に麻痺が残った部位



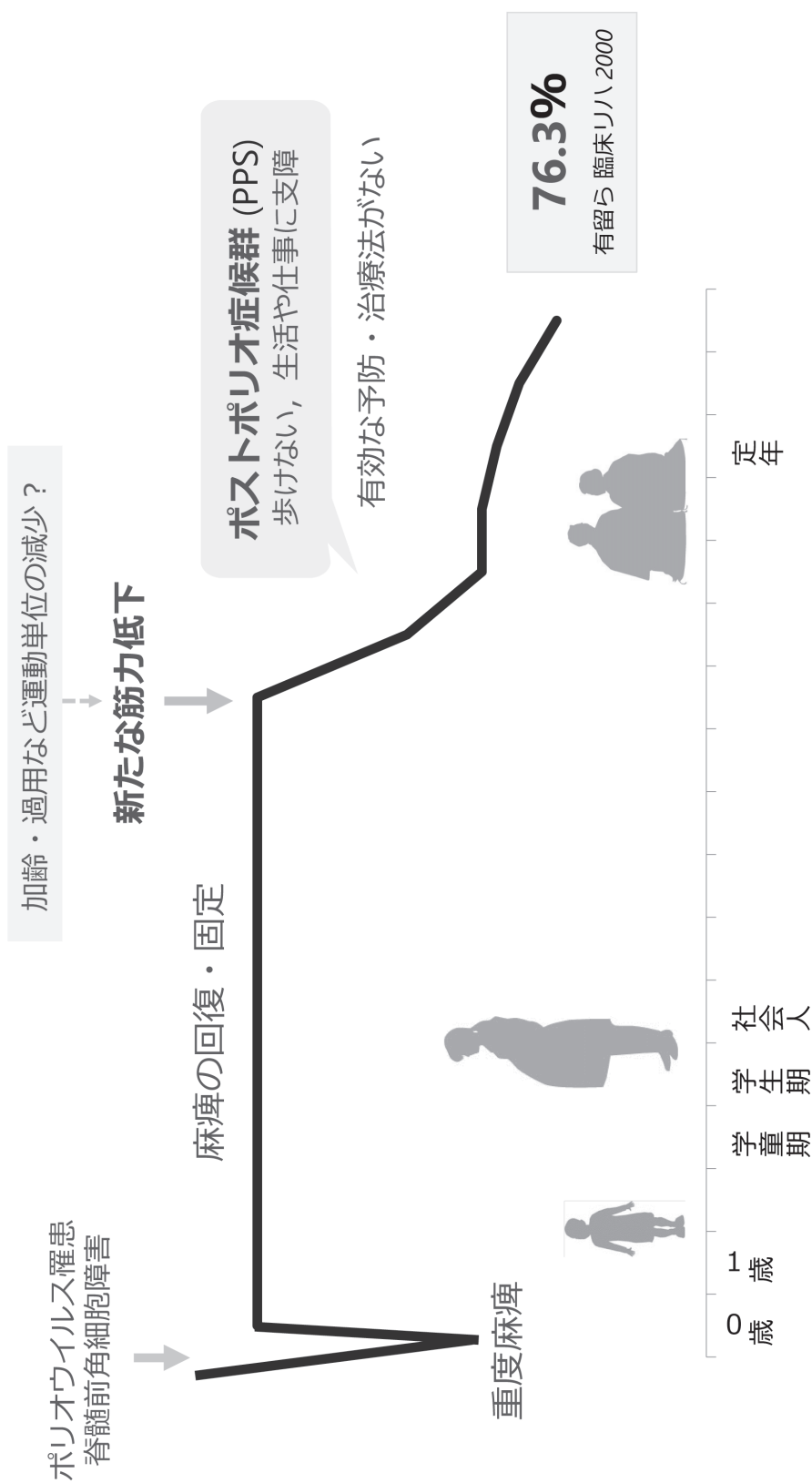
## ■ ポリオの臨床重症度 @ UOEH

n=43人, 各86肢



NRH肢体別重症度分類  
 軽 症 : NRH I, NRH II  
 中 等 症 : NRH III  
 重 症 : NRH IV, NRH V

### 3 ポストポリオについて



15年以上の安定期の後, 新たな筋力低下が出現する病態

# PPS 診断基準

## ■ HalsteadによるPPS診断基準（1987）

- (1) 麻痺性ポリオの確実な既往
- (2) 部分的または完全な神経学的・機能的回復
- (3) **少なくとも15年間の神経学的・機能的安定期間**
- (4) 安定期後に、以下の健康問題が2つ以上発生
  - ・ 普通でない疲労
  - ・ 関節痛／筋肉痛
  - ・ 麻痺側または非麻痺側の**新たな筋力低下**
  - ・ 機能低下
  - ・ **寒冷に対する耐性の低下**
  - ・ **新たな筋萎縮**
- (5) 以上の健康問題を説明する他の医学的診断がない

**PPS発症率 15～80 %**

\* 母集団や診断基準により異なる

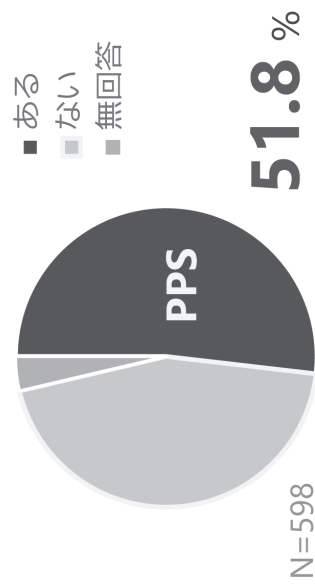
## ■ March of DimesによるPPS診断基準（2010）

- (1) 運動ニューロン消失を伴う**麻痺性ポリオの既往**（病歴：急性発症した麻痺性疾患，診察：筋力低下や筋萎縮の後遺症，**筋電図：脱神経所見**）．
- (2) 急性ポリオを発症し，部分的にあるいは完全な機能回復後に，**神経学的に機能が安定した状態**が一定期間（**通常15年以上**）あり．
- (3) 進行性で持続する**新たな筋力低下**や易疲労性（持久力減少）が徐々に，あるいは突然出現する．全身性疲労，筋萎縮，筋や関節痛を伴うことがある．PPS関連症状として，まれに，新たな呼吸や嚥下の問題を生じる．
- (4) これらの症状は1年以上持続する．
- (5) 同様の症状の原因となる他の神経疾患，内科疾患，整形外科疾患を除外する．

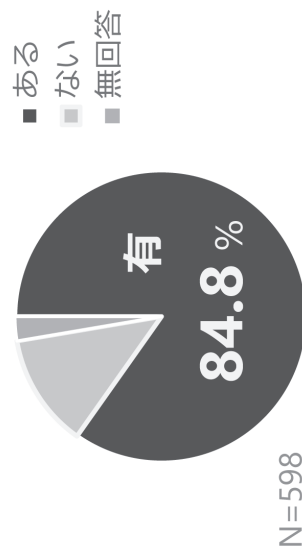


## PPS 診断率 51.8%, 症状増悪の自覚はさらに多い

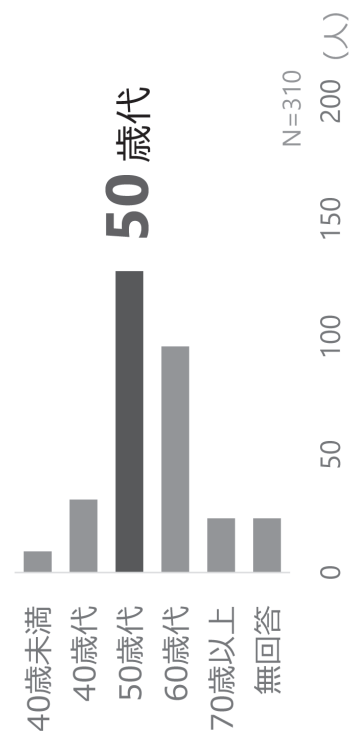
■ PPSの診断の有無



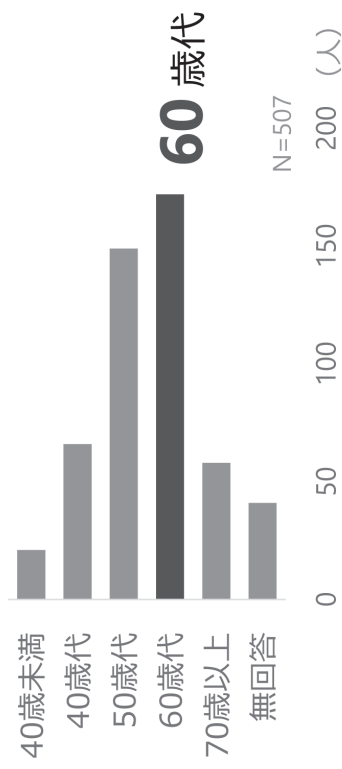
■ 症状が重くなったと感じている部位の有無



■ PPSの診断を受けた時期



■ 症状が重くなった時期

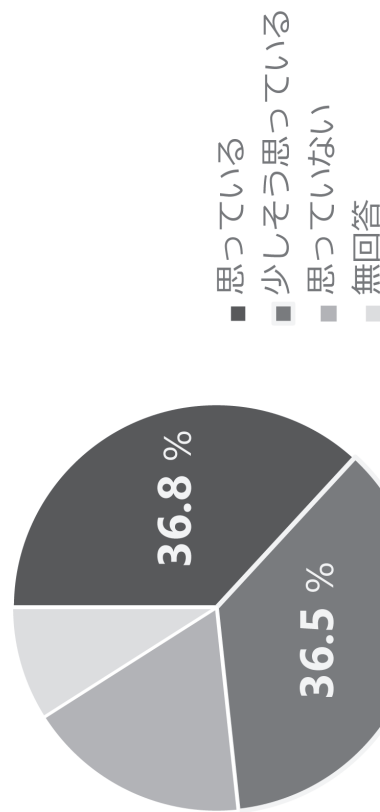


## 非PPS でも「PPSではないか」と思っている人は多い

### ■ 診断されていないが

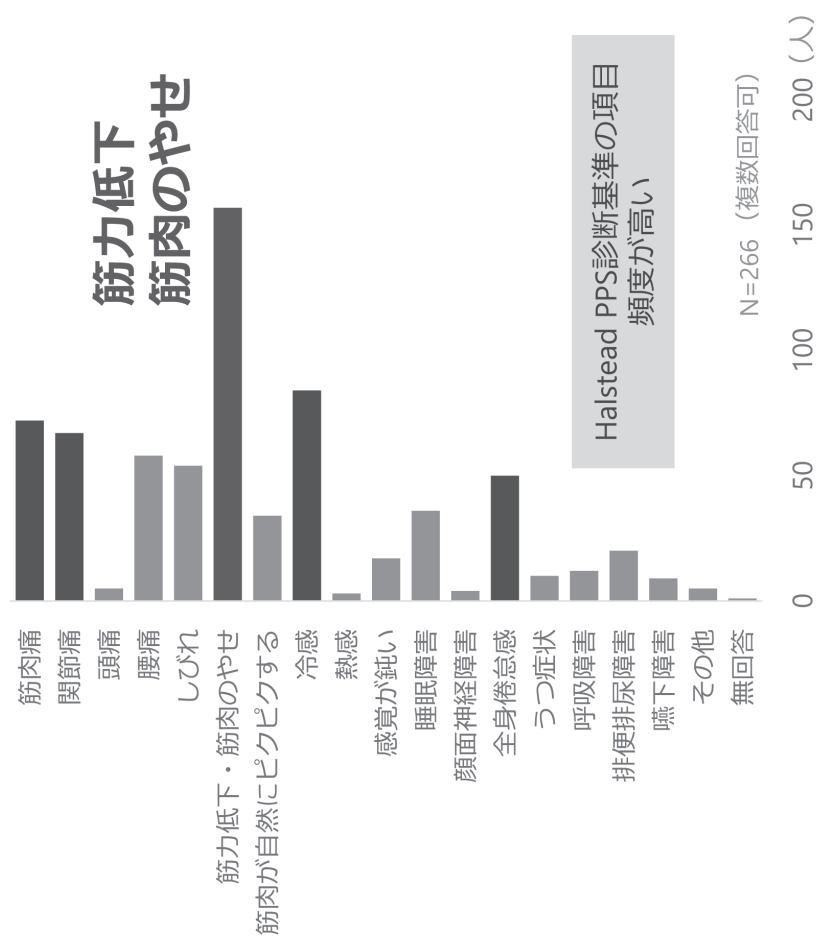
PPSではないかと思うことの有無

非PPSの 73.3 %



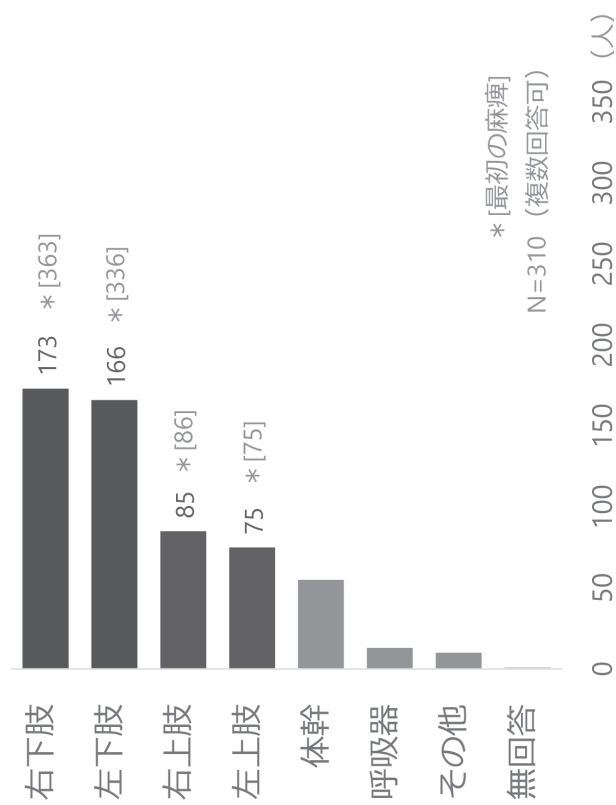
- ・ PPS まだ診断されていない？
- ・ 加齢？ その他疾患？

### ■ PPSではとされている症状

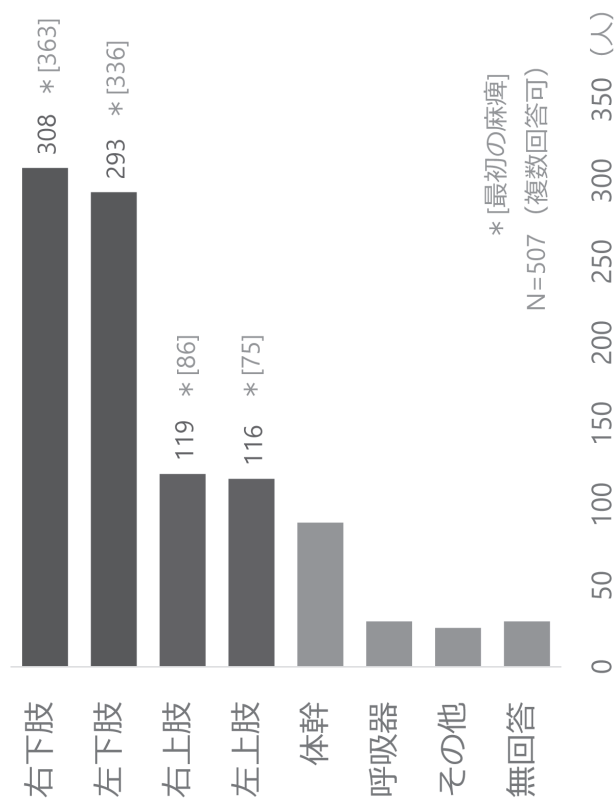


# 新たな筋力低下は、下肢が多い，上肢は「最初の麻痺」よりも増加

## ■ PPS診断前に新たに筋力低下が起きた部位

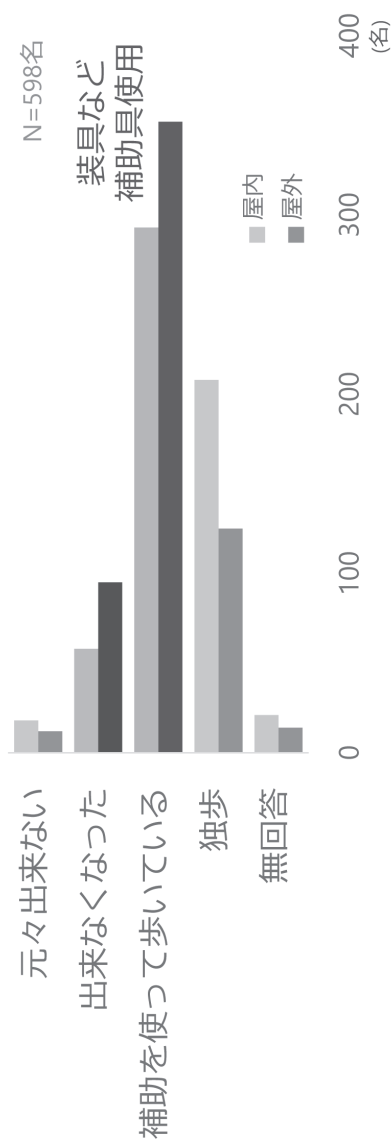


## ■ 症状が重くなった部位

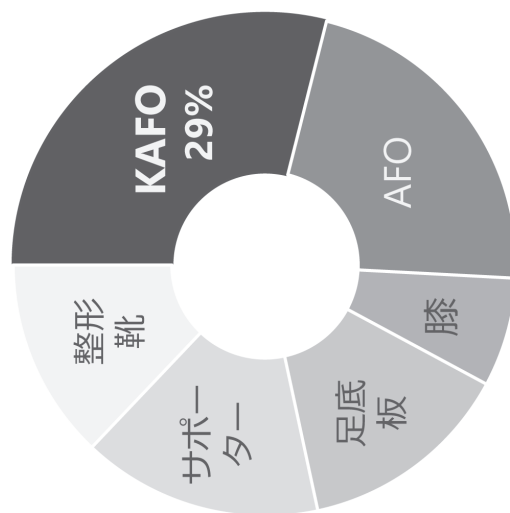


## 4 下肢の障害について - 歩行障害，補助具使用多い

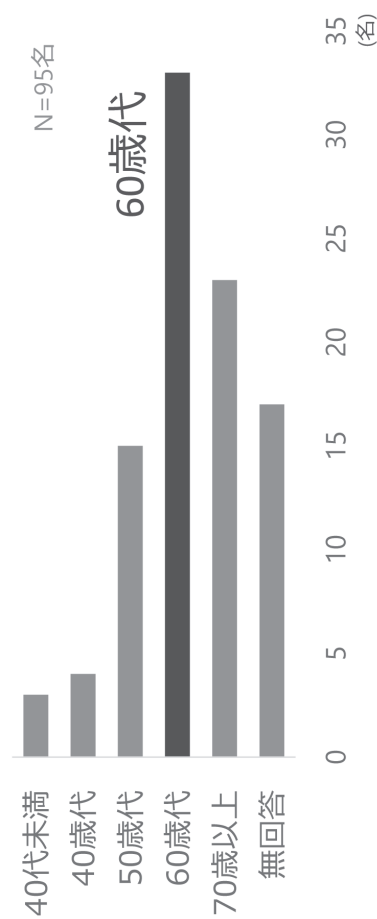
■ 歩くことの可否 (屋内・屋外)



■ 歩行のために使用している装具



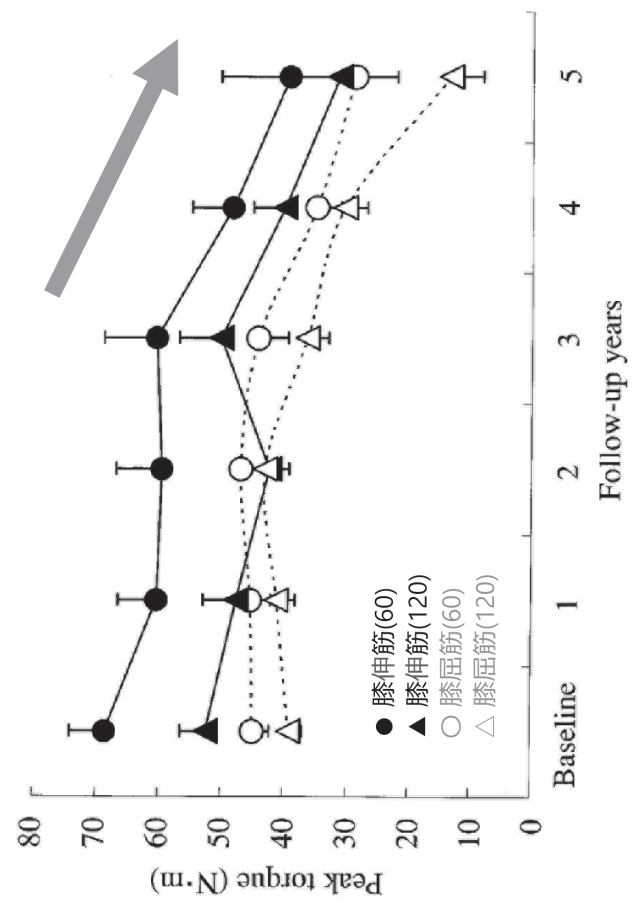
■ 歩くことが出来なくなった時期 (屋外)



# ポリオの下肢筋力@UOEH 経年的な筋力低下あり

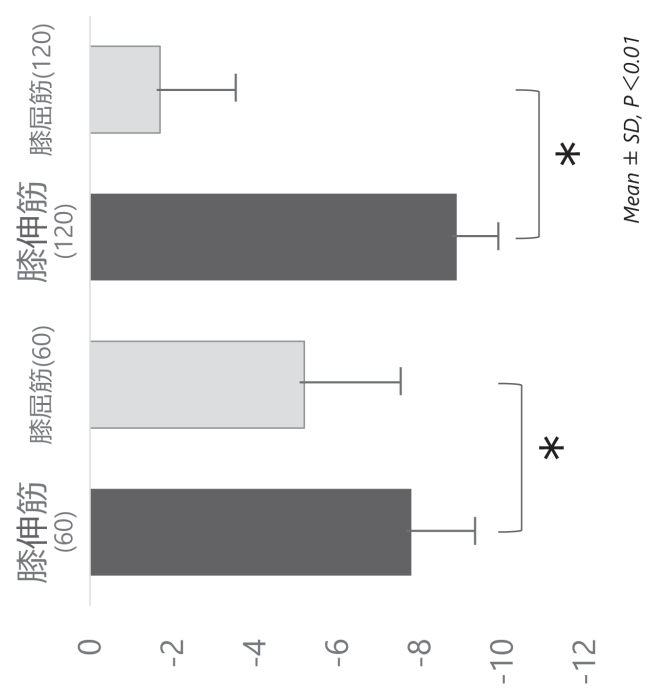
## 膝屈伸筋力 -5年間の変化

Biodex n=63名 (76肢) , 平均年齢 54.5歳



膝伸筋 > 膝屈筋群  
筋力低下の割合高い

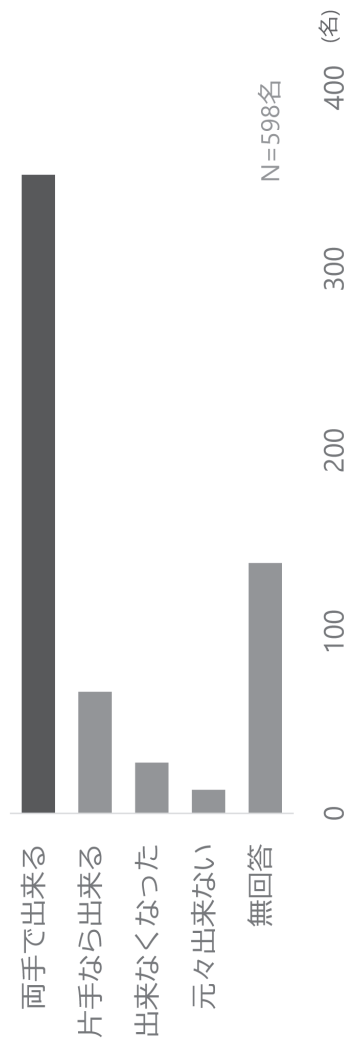
## 筋力ピークトルク値の年間変化率



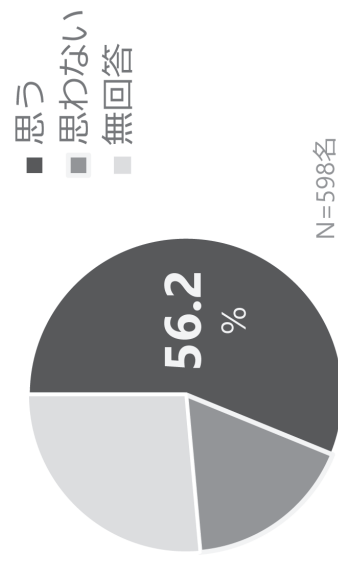
Saeki S, et al. J UOEH 2009

## 5 上肢の障害について - 握力低下自覚多い，能力は比較的保たれる

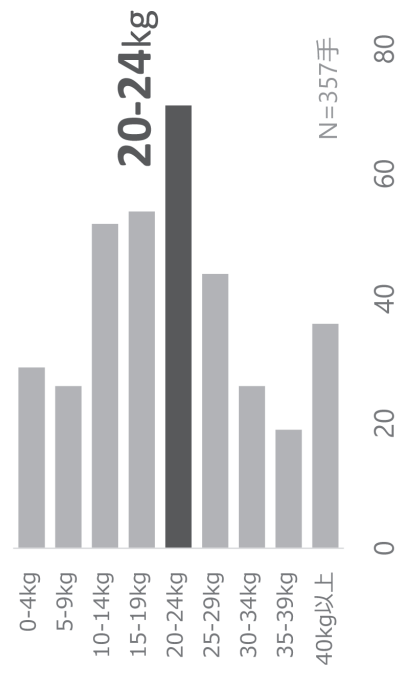
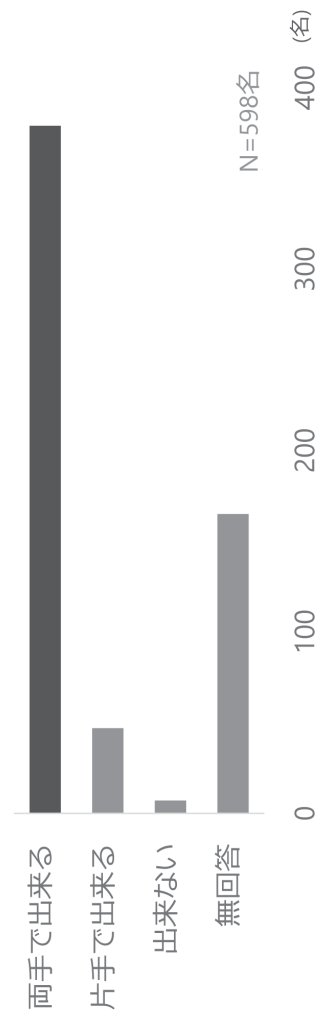
■ バンザイの可否



■ 握力が弱くなったと思うか



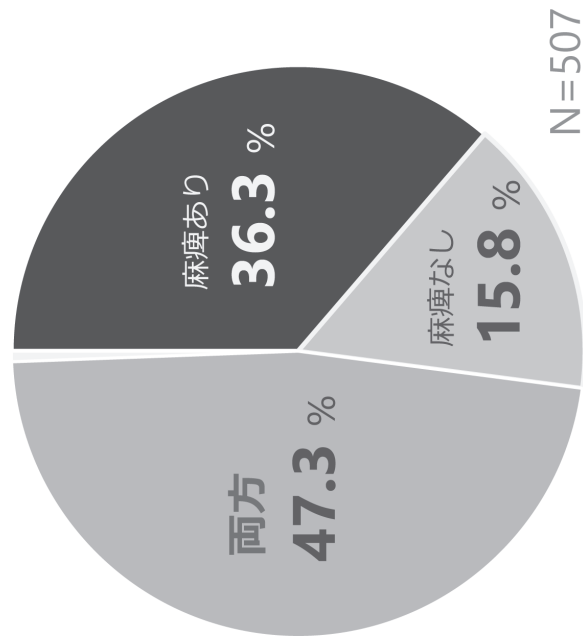
■ 手先の作業の可否



## 「麻痺自覚がない」部位の，症状増悪は多い

### ■ 症状が重くなった部位の状態

- 麻痺のあったところ
- 麻痺のなかったところ
- 両方
- 無回答

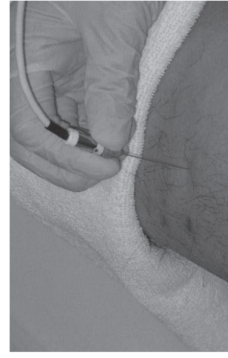
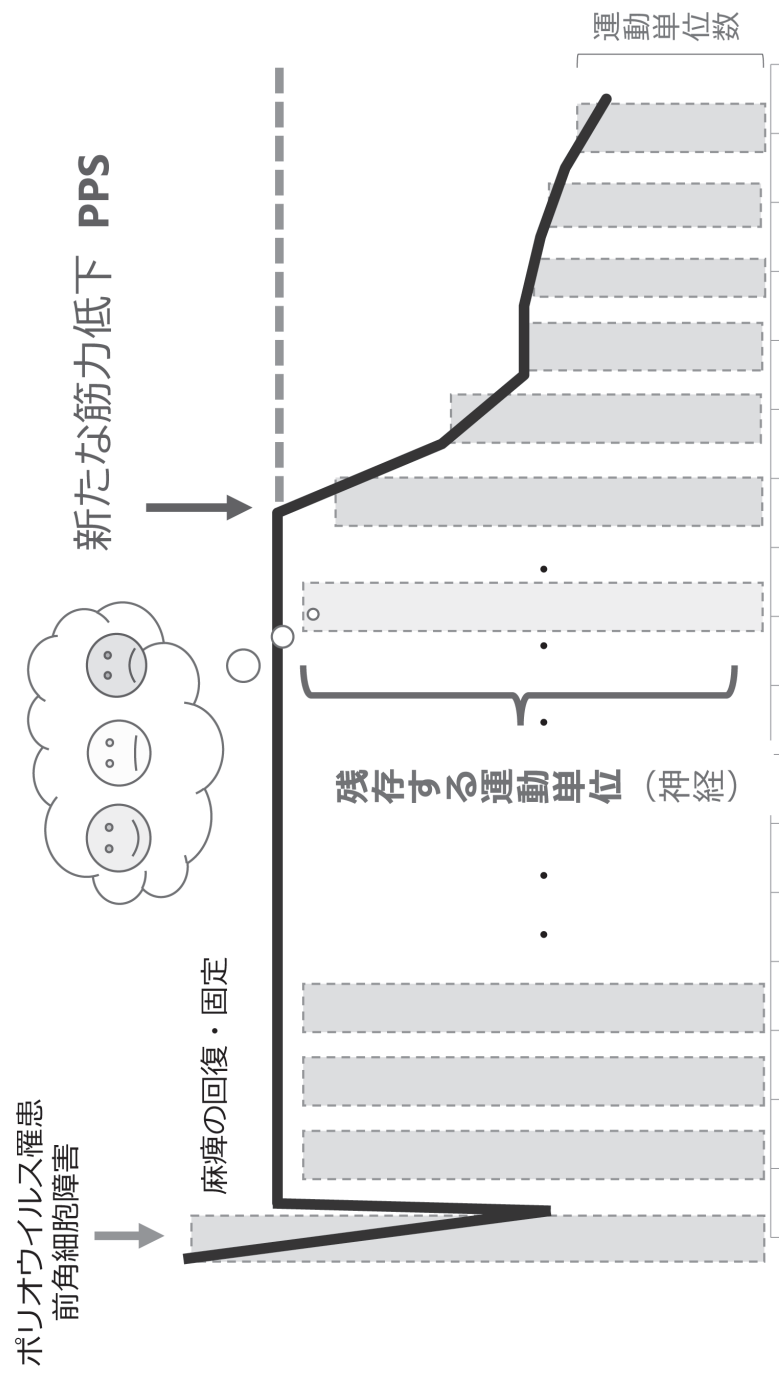


「麻痺の（自覚が）なかったところ」  
を含む症状増悪 **63.1 %**

**ポリオの病態をよく反映する結果**

\* ただし原因診断のため，一度病院受診を

## PPSと残存する運動単位（神経）



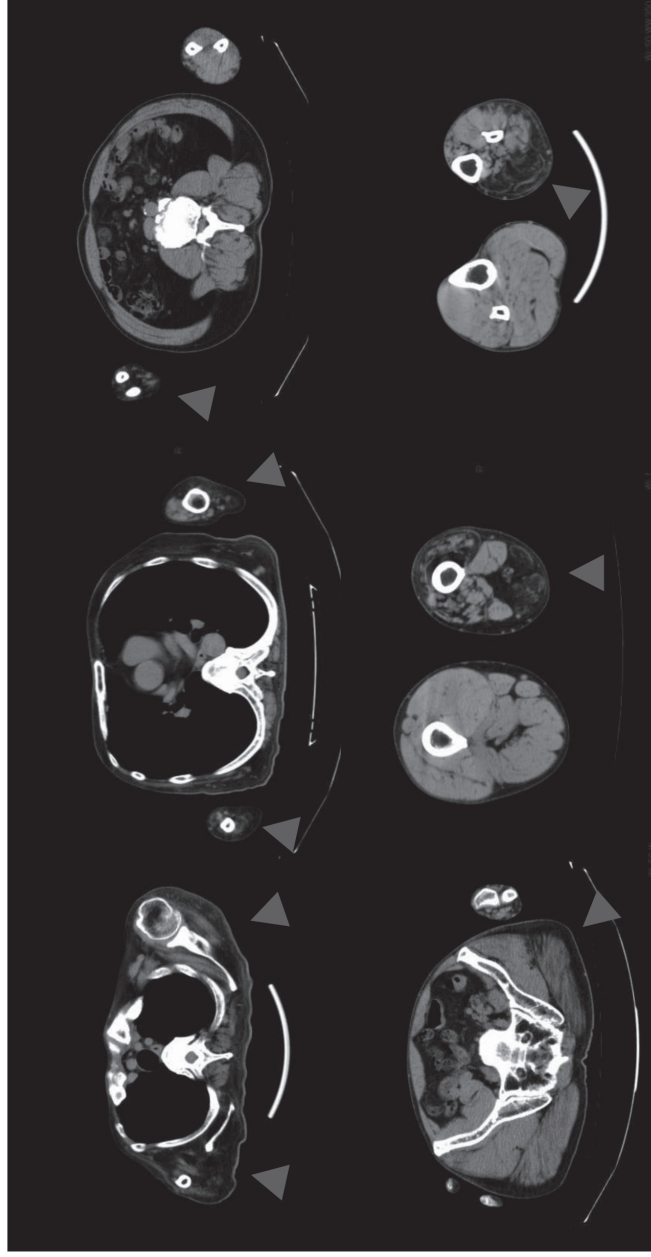
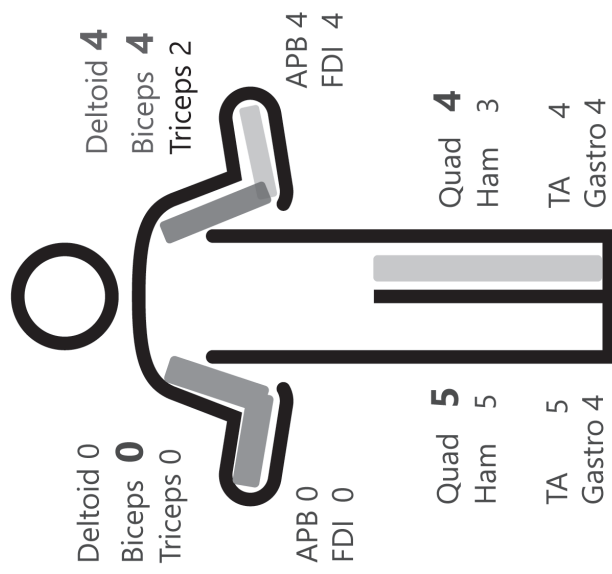
残存する運動単位（神経）の把握は、ポリオの病態理解に重要



# PPS症例・筋力・画像でみる運動単位

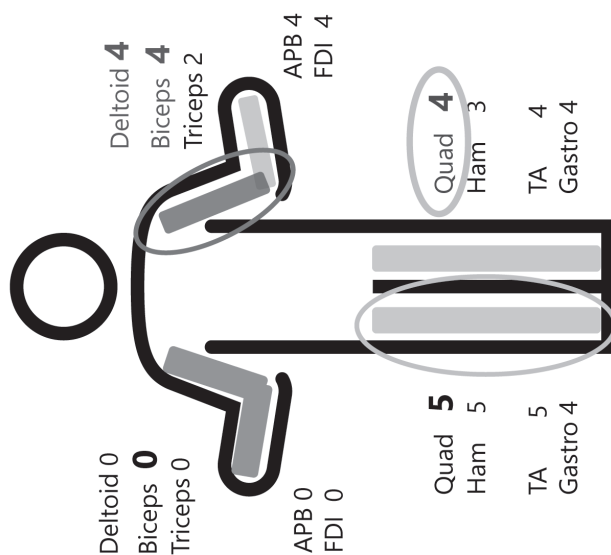
## ● 現病歴

3歳時にポリオ罹患，右上肢（重症），左上肢・左下肢（軽～中等症）の弛緩性麻痺後遺症  
 X-4年頃より左上肢の新たな筋力低下を自覚，X年（64歳時）当科紹介受診

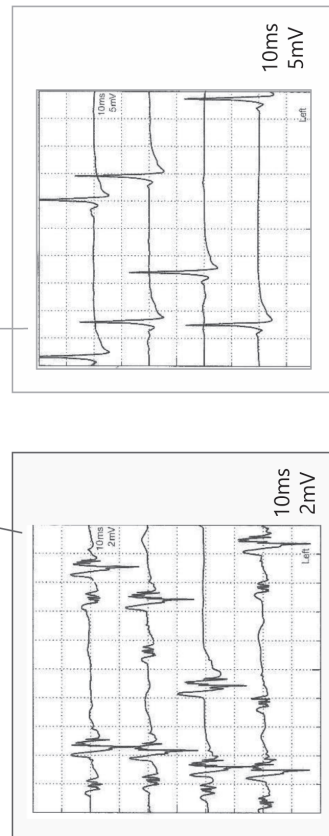


筋力低下が軽度の部位も，CTで筋萎縮や筋変性あり

# PPS症例・針筋電図で運動単位をみる



	Rest					Voluntary				
	Ins. Act.	Fib.	P-w.	Fasc.	Normal	Poly	Giant	Recruit-ment	Int. Patt.	
<b>R</b>										
Biceps	→	—	—	—	—	—	—	—	—	
Deltoid	→	—	—	—	1	2	1	Late	4	
<b>Biceps</b>	↑	1+	1+	—	0-1	2	2	Late	4	
Triceps	→	—	—	—	0	1	0	Late	2	
FDI	→	—	—	—	3	1	0	Normal	4	
PSM(C5)	→	—	—	—	2	2	0	Normal	4	
<b>R</b>										
Quad	→	—	—	—	0	2	1	Late	3	
Quad	→	—	—	1+	0	0	3	Late	2	
Gastro LH	→	—	—	—	0-1	2	1	Late	4	
<b>L</b>										

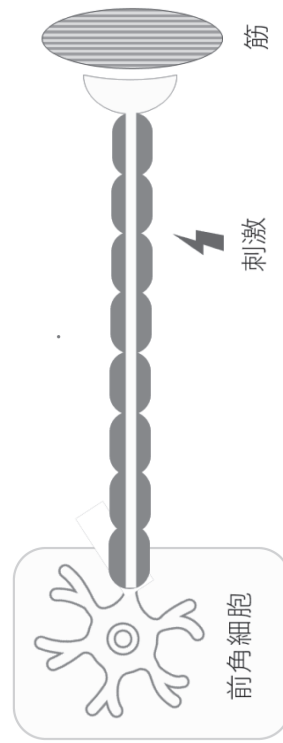


- 四肢に広範な慢性神経原性変化 — ポリオ既往
- 左上腕二頭筋に活動性脱神経所見 — PPS

筋力低下がない or 軽度の部位にも  
ポリオによる神経原性変化あり

## ポリオ・F波で運動単位をみる

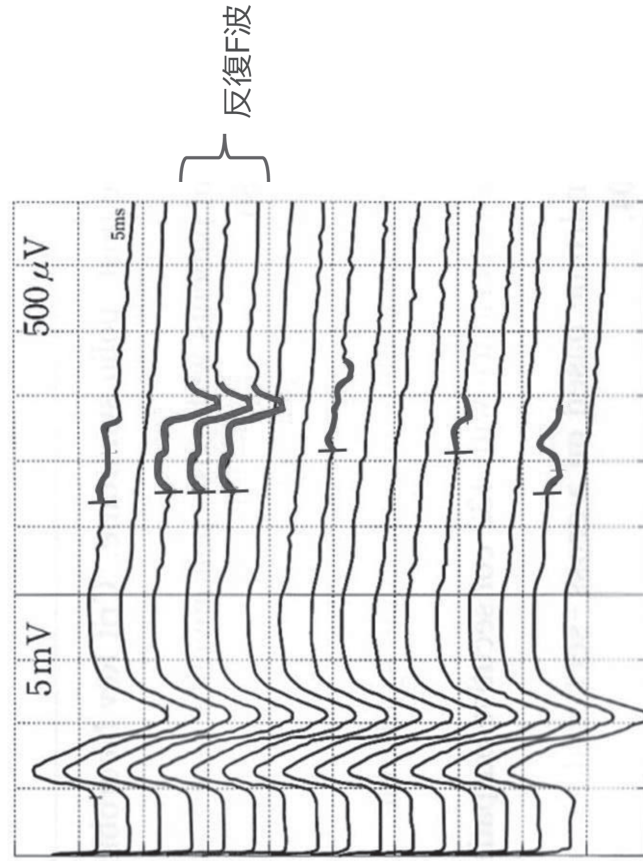
F波はポリオによる  
前角細胞障害を反映するのでは？



- F波出現率の低下
- 反復F波

ポリオウイルス感染

【計測例】



\* 反復F波：潜時・振幅・波形が同一なF波

## ポリオ・F波で運動単位をみる

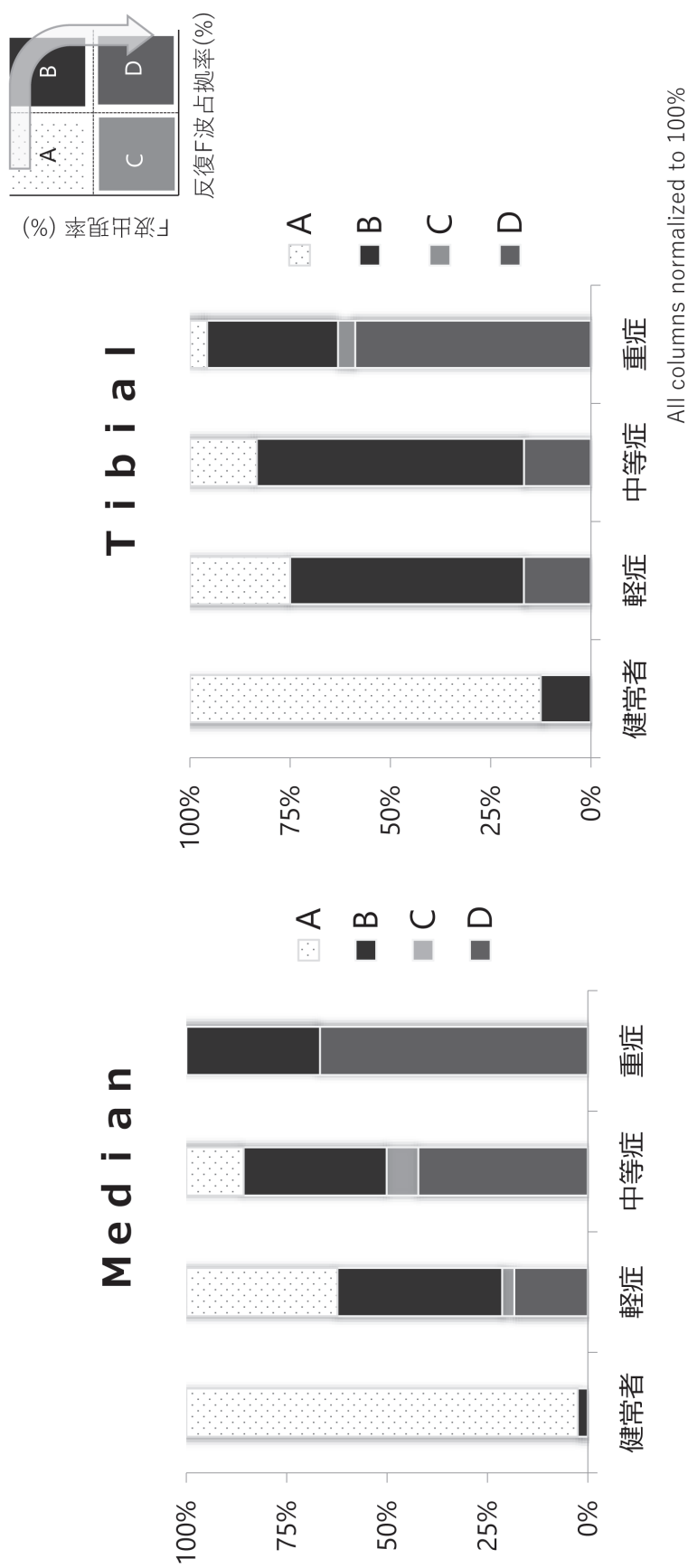
- ポリオ罹患者43名（うちPPS 20名）と健康コントロール20名

	Median		Tibial	
	ポリオ罹患者	健康者	ポリオ罹患者	健康者
<b>運動神経伝導検査</b>				
DML(ms)	4.4 ± 4.2	3.6 ± 0.6	3.8 ± 1.0	3.4 ± 0.6
CMAP(mV)	5.1 ± 2.8	6.7 ± 2.5	6.9 ± 5.8	13.1 ± 4.7
MCV(ms)	58.4 ± 7.3	60.1 ± 3.6	50.0 ± 8.0	100.0 ± 3.6
<b>F波</b>				
<b>F波出現率(FP) (%)</b>	<b>60.7 ± 27.5 ↓</b>	79.5 ± 14.9	<b>84.4 ± 28.1 ↓</b>	100.0 ± 0.0
<b>反復F波総数 (/100回刺激)</b>	<b>21.9 ± 15.6 ↑</b>	8.0 ± 5.6	<b>17.9 ± 19.8 ↑</b>	1.0 ± 1.7
<b>反復F波占拠率(ORF) (%)</b>	<b>41.3 ± 26.6 ↑</b>	10.6 ± 7.4	<b>27.9 ± 31.8 ↑</b>	0.6 ± 1.6
F-latency (ms)	25.7 ± 2.9	23.8 ± 1.6	44.6 ± 4.8	44.0 ± 3.7
F-amplitude (μV)	113.4 ± 71.0	89.4 ± 39.4	162.9 ± 94.6	144.6 ± 63.9
<b>運動単位数推定</b>				
<b>MUNE (APB, AH)</b>	<b>96.9 ± 84.4 ↓</b>	224.1 ± 63.4	<b>186.7 ± 184.8 ↓</b>	387.4 ± 151.0

ポリオ F波異常が多い, 運動単位数が少ない

Hachisuka, et al. Muscle Nerve 2015

# ポリオ・F波で運動単位をみる

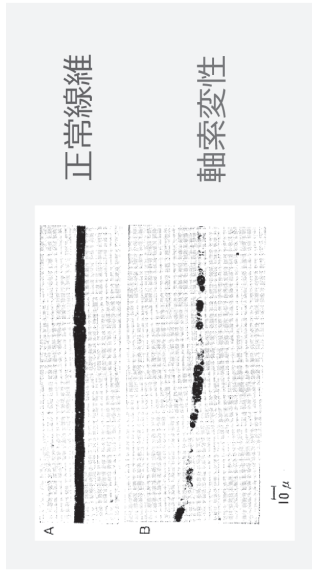
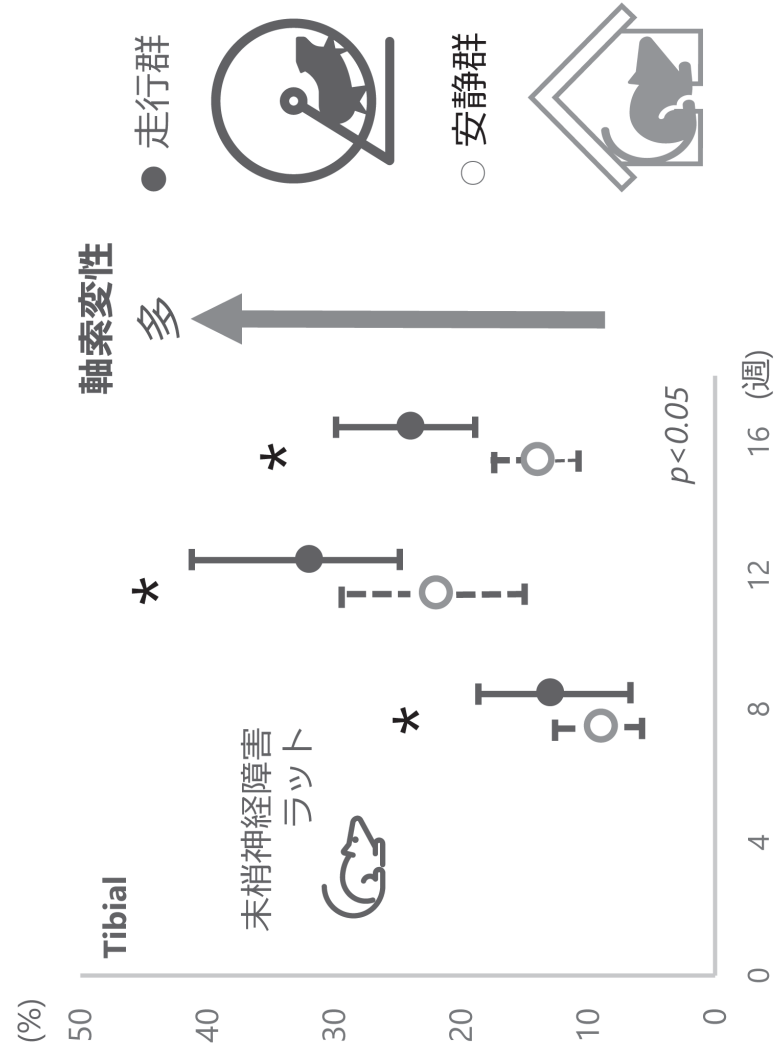


臨床症状がない軽症で，半数以上にF波異常あり

早い段階から運動単位の減少を示唆

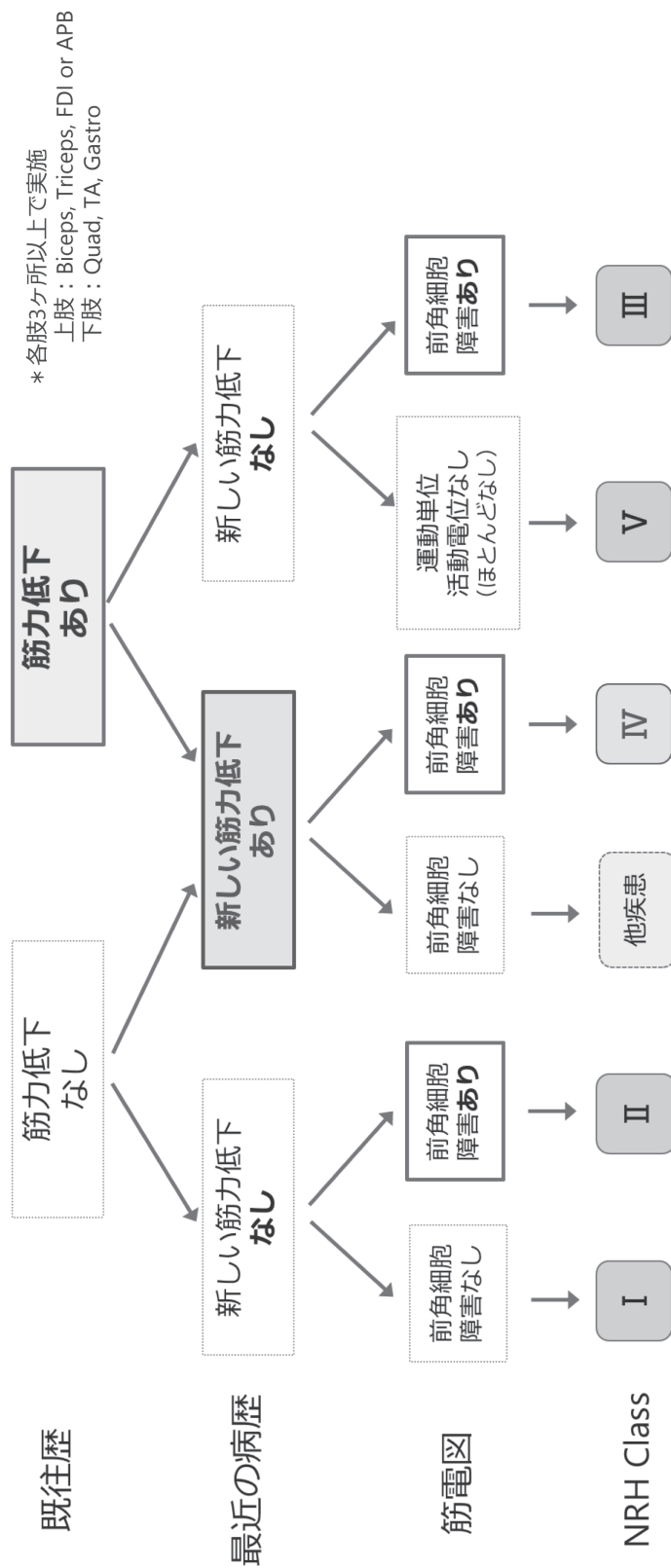
# Overwork weakness -運動と筋力-

軸索変性線維の出現率



- 末梢神経障害において、  
過度の身体的活動に起因して  
筋力低下を呈する病態
- “過用性筋力低下”とも言う。

# NRH ポリオ後肢体分類 アルゴリズム



- ・ 安全で適切な運動療法処方のため、病歴・身体所見・筋電図を組み合わせたもの
- ・ 筋毎に個別評価し、各肢で最も障害を受けた筋により分類

Halstead LS et al. Post-polio syndrome. 1995より一部改変  
蜂須賀ら, Jpn Rehabil Med 2020

# NRH分類と運動プログラム

NRH	強度		頻度	1回の運動時間	運動ペース	目標
Class I No clinical polio	最大心拍数60～80%	6～9METs	週3～5日	15～30分	—	筋力増強，心耐久性向上
Class II Subclinical polio	最大心拍数60～80%	5～7METs	週3～4日 隔日	15～30分	4～5分運動 1分休憩	適度な筋力向上（障害筋） 筋力維持（正常筋）
Class III Clinically stable polio	—	4～5METs	週3～4日 隔日	15～20分	2～3分運動 1分休憩	筋力維持（障害筋） 可能な場合は筋力向上
Class IV Clinically unstable polio	—	≤ 3METs	週2～3日 隔日	10～15分	2～3分運動 1～2分休憩	筋力低下進行の予防（障害筋）
Class V Severely atrophic polio	日常生活の活動 （装具や車椅子が必要）		—	—	—	（関節可動域の維持）

\* 新たな筋力低下，疼痛，疲労感が出現したら，運動療法の縮小や中止，装具使用などを検討する。

Halstead LS et al. Post-polio syndrome. 1995  
Halstead LS, et al. Disabil Rehabil. 1996  
蜂須賀ら, Jpn Rehabil Med 2020

- ・ 原法通りでなくとも，多面的に病態を捉える概念は有用
- ・ 臨床的には，翌日に筋肉痛が残らない程度，CK値が上昇しない程度



# 装具の軽量化で負担軽減



カーボン製KAFO  
約900g



従来型KAFO  
約1400g



↓  
負荷軽減

## 従来型KAFO vs カーボン製KAFO

	従来型 KAFO	カーボン製 KAFO
歩行率 (歩/min)	92.9 ± 6.3	92.0 ± 11.1
歩幅 (cm)	41.3 ± 7.0	45.7 ± 8.2
歩行速度 (m/min)	38.5 ± 7.0	42.6 ± 7.8 *
酸素摂取量 (m/min/kg)	14.0 ± 3.2	12.8 ± 2.4 *
酸素コスト (ml/m/kg)	0.37 ± 0.08	0.32 ± 0.09 *
Physiological cost index	0.95 ± 0.36	0.81 ± 0.43 *

Paired t-test \*p<0.05

- ・ 従来型KAFO使用しておりカーボン製KAFOを作製した8名
- ・ 5 分間の快適歩行

Hachisuka K, et al. J Rehabil Med. 2007

## まとめ

- 全国ポリオ会連絡会のアンケート結果は、平均年齢 70.1 歳，PPS 診断率 51.8% ，症状が重くなったと感じる部位がある方は 84.8% であった。
- 新たな筋力低下を「麻痺の（自覚が）なかったところ」に生じたのは 63.1% と多かった。ポリオの背景にある運動単位数減少に由来する可能性あり，症状がない，または軽度の場合にも，しばしば運動単位数の減少を認める。
- ポリオの運動療法では，個々の病態を考慮した負荷量の工夫が望ましい。
- 症状増悪の原因として，ポリオや加齢による影響が考えられる。ただし，個々の診断は，一度，医療機関を受診する必要がある。

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蜂須賀 明子 松嶋 康之 佐伯 覚

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

## はじめに

ポリオ罹患者では高負荷の動作を繰り返すことで過用性筋力低下や不活動による廃用性筋力低下を引き起こす可能性があることから、日常生活の身体活動量を把握することは重要である。身体活動は運動と生活活動に大別することができ、運動に加えて日常生活における身体活動を増やすことは疾病予防やメンタルヘルスの改善、高齢者の生活機能低下リスクの低減に繋がると身体活動ガイドラインで示されている。ポリオ罹患者の身体活動の適正化を図るには、身体活動量の測定を行い各対象者の生活リズムや運動習慣、余暇活動について把握した上で対象者に合わせた指導を行っていくことが望ましいが、これらの報告はほとんどない。当院ではポリオ罹患者を対象とした相談会を年1回実施しており、2021年からは三軸加速度センサー内蔵活動量計（以下、活動量計）を用いた身体活動量の調査と運動指導、生活指導を行っており、その実際について報告する。

## 方法

**対象** 2021年から2022年に実施したポリオ相談会に参加し、活動量計の調査を希望したもの

**方法** 機器：三軸加速度センサー内蔵活動量計（Active style pro HJA-750C, オムロンヘルスケア社）  
測定：活動量計は郵送にて配付し、入水時を除いて起床時点から就寝時点まで連続7日間測定した。腰部に装着し、可能な限りズボンを着用した（ズボン着用が困難な場合は専用ベルトを装着）  
測定中に身体活動への影響を最小限にするため、活動量及び歩数等を非表示に設定した。  
対象者には、機器を装着している際は普段と同様の生活を送って頂くように指導した。  
時間帯毎の活動内容（図1 生活記録表）を記載してもらい、具体的な活動内容を把握した。



**データ** 1日10時間以上データが得られた日を解析対象とし、4日以上有効な装着記録があることを条件とした。

中高強度身体活動（MVPA：moderate-to-vigorous physical activity）	3.0METs以上
低強度身体活動（LPA：light-intensity physical activity）	1.5METsより高く、3.0METs未満
座位行動（SB：sedentary behavior）	1.5METs以下

## 結果

表1 対象者の基本属性、身体活動量の実際

n=14	n (%), mean±SD
年齢（歳）	68.7 ± 4.8
女性	5 (35.7)
移動関連項目	
歩行自立度：FAC*（4/5/6）	1/3/10
短下肢装具/長下肢装具	3/6
車椅子使用者	6 (42.9)
Barthel Index（点）	95.1 ± 11.7
身体活動量	
歩数（歩）	2644.3 ± 3214.7
歩行時間（分/日）	48.3 ± 32.6
総活動時間（分/日）	868.2 ± 119.4
SB（分/日）	597.8 ± 152.1
LPA（分/日）	286.6 ± 117.6
MVPA（分/日）	41.7 ± 47.0

\*：Functional Ambulation Classification



図1 生活記録表の1例

活動量計データと生活記録表を照合し、

各対象者ごとに生活指導や運動指導を実施した。

- ・SBが長い場合（図1 青丸）は、LPAの確保や適度な運動を促進する。
- ・MVPAが10分以上持続する場合（図1 赤丸）は、こまめな休憩を行う。
- ・車椅子併用例でLPAやMVPAが少ない場合は、座位の運動を促進する。

## 考察

中強度(3~6METs)の有酸素性の身体活動を少なくとも150~300分/週実施することが推奨されている。

(WHO身体活動・座位行動ガイドライン)

➡ ポリオ罹患者のMVPAは平均292分/週であり、推奨時間を達成できたのは7例（50%）で個人差を認めた。

活動量計の欠点は、活動のドメイン（仕事なのか余暇なのか）や具体的な活動の種類を捉えられないものが多い。

(田島 敬之、理学療法、2023)

➡ 生活記録表をすることで具体的な活動内容が把握できるため、具体的な運動指導や生活指導が可能となる。

## まとめ

活動量計データと生活記録表を照合することで、ポリオ罹患者の個人特性に合わせた具体的な生活指導が実施できた。今後は症例数を増やして、身体活動特性の調査および指導の効果検証を行っていく。

## ポリオ罹患者の腰痛が日常生活に及ぼす影響

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## — Key Words —

腰痛, ポリオ, 検診

【背景】当院では、ポリオ罹患者を対象とし、1年に1回検診を実施している。今回ポリオ罹患者を対象に自記式質問紙を用いて、腰痛が日常生活活動（activities of daily living：ADL）、生活の質（quality of life：QOL）、心理社会的因子に与える影響について検討した。【対象・方法】2020年郵送形式の検診に参加したポリオ罹患者55名（男性22名、女性33名、平均年齢67.9±5.3歳）を対象とし解析した。評価項目は、患者特性、腰痛、ADLおよびQOL、心理社会的因子、自己効力感、活動量とした。【結果】腰痛の有訴率は45.5%であった。腰痛群は、非腰痛群と比較して、ADL、QOL、自己効力感は有意に低下し、心理社会的因子の1つである破局的思考は有意に増大していた。また腰痛の程度は、年齢、ADL、QOL、自己効力感、破局的思考および活動量と関連していた。【結語】ポリオ罹患者の腰痛は、移動の自己効力感や活動量を低下させ、ADLおよびQOLを低下させる悪循環を引き起こす可能性が示唆された。

## はじめに

腰痛は高齢者で頻度が高い疾患であり、日常生活活動（activities of daily living：ADL）および生活の質（quality of life：QOL）に大きな影響を及ぼす。2019年国民生活基礎調査では、腰痛は65歳以上の男女ともに有訴率1位であった<sup>1)</sup>。近年、高齢者および勤労者における腰痛予防の試みが報告されている<sup>2,3)</sup>が、まだ体系的なアプローチは確立していない。

筆者らは全国に先駆けて、2001年より北部九州・山口地区を中心とするポリオ患者会（エンジョイポリオの会）のポリオ罹患者を対象とする検診を年1回開催し、障害管理システムの構築に取り組んでいる。検診では、ポリオに伴う新たな障害の早期発見・予防を目的として、身体機能（関節可動域および筋力など）やADLおよびQOL、就業状態、ポストポリオ症候群（post-polio syndrome：PPS）に

伴う症状や歩行障害など、ポリオ罹患者が抱える問題点に対して、評価・指導・追跡・データ管理を行っている。

ポリオは、主としてポリオウイルスが脊髄前角細胞に感染し、その神経支配領域に弛緩性運動麻痺を来すウイルス性疾患である。PPSは、ポリオ罹患後、ある程度まで機能的に回復し、15年以上の安定期の後、新たな筋力低下や筋萎縮を生じる病態である<sup>4)</sup>。PPSの背景に、さまざまな誘因による運動単位の変性や減少が示唆されている。ポリオ罹患者において、加齢に伴う下肢筋力の低下率は健常高齢者と比較して大きく<sup>5)</sup>、ポリオは早期加齢モデルとも考えられる。近年、ポリオ罹患者の高齢化に伴い、PPSに加えて、腰痛など運動器関連疼痛が問題視されているが、本邦における報告は少ない。

本研究の目的は、ポリオ罹患者における腰痛の有訴率を調査し、腰痛がADLおよびQOL、心理社会的因子、歩行に関する自己効力感、身体活動量に与

The impact of low back pain on activities of daily living for polio survivors

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(受稿日：2022年12月26日)

\*利益相反：なし



表 1 患者背景

参加者 (n=55)

年齢（歳）		67.9 ± 5.3
性別（男性/女性：人）		22/33
発症年齢（歳）		1.6 ± 1.1
NRH 分類 (Class I / II / III / IV / V : 肢)	右上肢	39/4/10/2/0
	左上肢	37/6/11/1/0
	右下肢	4/1/13/13/24
	左下肢	7/3/12/13/20
	体幹	34/6/11/3/1

平均値 ± 標準偏差, NRH : National Rehabilitation Hospital

える影響を明確にすることである。

## 対象

2020年に、郵送形式で開催した検診に参加したポリオ罹患患者55名(男性22名、女性33名、平均年齢67.9±5.3歳)を対象とし解析した(表1)。参加者は、患者会を通じて募集した。

## 方法

参加者に対して、問診票を郵送した。評価項目は、患者特性、腰痛、ADLおよびQOL、心理社会的因子、歩行に関する自己効力感、身体活動量を用いた。今回、腰痛の定義は、直近1か月における腰痛があり、疼痛程度がVisual Analogue Scale (VAS)において30 mm以上<sup>6)</sup>とし、腰痛群と非腰痛群の2群に分けた。本研究は、産業医科大学の倫理委員会にて承認を得た(承認番号281423)。

### 1. 患者特性

年齢、性別、側弯の有無、運動習慣の有無、発症年齢、National Rehabilitation Hospital (NRH) 肢体別重症度分類(NRH分類)<sup>7)</sup>を調査した。NRH分類は、各肢の筋を評価し、最も障害を受けた筋により分類する。今回、四肢におけるNRH分類の平均値を独自に算出して用いた(NRH分類の四肢平均)。

### 2. 腰痛

腰痛の程度はVAS<sup>8)</sup>を用い、左端が「痛みなし」、右端が「これまでに感じた最大の痛み」として、現在感じている痛みの程度を線上に示してもらった。

また、その長さを数値化した(単位:mm)。

### 3. ADL および QOL

ADLはBarthel Index (BI)、応用的日常生活動作能力(Frenchay Activities Index : FAI)、QOLはMOS Short Form 36-Item Health Survey (SF-36<sup>®</sup>)<sup>9)</sup>を用いた。BIはBI修正版の1つ「産医大版Barthel Index自己評価表」<sup>10)</sup>を用いた。13項目より構成され、点数は0~100点(高得点ほどADLの自立度が高い)である。FAIは改訂版FAI自己評価法<sup>11)</sup>を用いた。日常生活の応用的な活動や社会生活に関する評価法で、15項目より構成され、点数は0~45点(高得点ほど活動的)となる。SF-36<sup>®</sup>は包括的健康関連QOL評価法で36項目よりなる自記式質問紙法であり、8つの概念領域を下位尺度として測定する。さらに8つの下位尺度の因子分析の結果をもとに身体的健康(physical component summary : SF-36<sup>®</sup>-PCS)と精神的健康(mental component summary : SF-36<sup>®</sup>-MCS)の2つから構成される。

### 4. 心理社会的因子

心理社会的因子は、痛みの破局的思考尺度(Pain Catastrophizing Scale : PCS)<sup>12)</sup>、日本語版Hospital Anxiety and Depression Scale (HADS)<sup>13)</sup>を用いた。PCSは疼痛に関する破局化を13項目で評価し、反芻(痛みに関連した考えに過剰に注意を向けること)、無力感(痛みの強い状況への対処において無力なものへ目を向けること)、拡大視(痛みの脅威を過大評価すること)の3つの下位尺度から構成される。それぞれは0点(まったくあてはまらない)~4点(非常にあてはまる)で評価し、合計点が高いほど破局化傾向が強い。HADSは不安(7項目)と抑うつ(7項目)の2因子、合計14項目(各1~3点)で構成される。合計点が高いほど不安・抑うつが強く、8点以上で疑いがあると判断する。

### 5. 歩行に関する自己効力感

歩行に関する自己効力感は、日本語版-改訂Gait Efficacy Scale (GES)<sup>14)</sup>を用いた。10項目の質問で構成され、各項目を1点(まったく自信がない)~10点(完全に自信がある)のリッカート尺度で評価し、合計得点(10~100点)を算出する。なお、質問に

おける歩行環境条件は、床板のような固い平面上、芝生の上、通路の障害物の回避、階段昇降、長距離歩行などがある。

## 6. 身体活動量

身体活動量は、国際標準化身体活動質問票 (International Physical Activity Questionnaire : IPAQ) Short 版<sup>15)</sup>を用いた。歩行、中等度の身体活動、強い身体活動、座位時間から構成され、それぞれの時間(分)と日付(日)を記載する。解析では、歩行 3.3 metabolic equivalents (METs)、中等度の身体活動 4.0 METs、強い身体活動 8.0 METs として、時間と頻度に基づき身体活動量を算出した<sup>16)</sup>。

## 統計解析

正規性の解析には、Shapiro-Wilk 検定を用いた。また腰痛の有無による 2 群間の比較には、Student の t 検定、 $\chi^2$  検定および Wilcoxon の順位和検定を用いた。腰痛の程度と各項目との相関には、Pearson の積率相関係数および Spearman の順位相関係数を用いた。すべての統計学的解析には SPSS ver.25.0 (IBM 社) を用い、統計学的有意水準は 5% とした。

## 結果

参加者の問診票回答率は 100% であった。ポリオ罹患患者における腰痛の有訴率は 45.5% であった。腰痛群は非腰痛群と比較して、BI (腰痛群  $89.1 \pm 15.4$ , 非腰痛群  $96.7 \pm 10.3$ ), SF36-PCS (腰痛群  $33.7 \pm 8.1$ , 非腰痛群  $43.5 \pm 8.0$ ), GES (腰痛群  $29.3 \pm 17.6$ , 非腰痛群  $47.9 \pm 22.7$ ) は有意に低く、NRH 分類の四肢平均 (腰痛群  $3.0 \pm 0.7$ , 非腰痛群  $2.4 \pm 0.7$ ), PCS の無力感 (腰痛群  $7.2 \pm 4.3$ , 非腰痛群  $4.5 \pm 4.7$ ) は有意に高値であった (表 2)。また腰痛の程度は、年齢 ( $r=0.40$ ), PCS の無力感 ( $r=0.40$ ) と有意に弱い正の相関を認め、BI ( $r=-0.40$ ), FAI ( $r=-0.34$ ), SF36-PCS ( $r=-0.59$ ), GES ( $r=-0.41$ ), IPAQ の高強度 ( $r=-0.35$ ) と有意な中等度から弱い負の相関を認めた (表 3, 図)。しかし、腰痛の程度と NRH 分類の四肢平均値は有意な相関を認めなかった。

## 考察

本研究では、ポリオ罹患患者における腰痛の有訴率を調査し、腰痛が与える影響を検討した。今回腰痛

群では、BI, SF-36<sup>®</sup>-PCS, GES は有意に低く、NRH 分類の四肢平均、PCS の無力感は有意に高値で不良であった。また、腰痛の程度は、年齢、ADL および QOL、心理社会的因子の 1 つである破局的思考、歩行に関する自己効力感、身体活動量と関連を認めた。

同年代の健常高齢者を対象としたコホート研究では、腰痛有訴率が 36.7<sup>17)</sup>~41.7%<sup>18)</sup> (男性 39.5%, 女性 43.2%) と報告される。今回、ポリオ罹患患者の腰痛有訴率は 45.5% と、同年代の健常高齢者よりも高かった。また、ポリオ罹患患者における先行研究<sup>19)</sup>でも、腰痛の有訴率は同年代健常高齢者より高値 (53.2%) であった。今回、急性~慢性腰痛を含み得る中等度~重度の腰痛が対象であり、軽症を含む全体の腰痛有訴率はさらに高値であると推定される。

腰痛の危険因子として、身長低下<sup>18)</sup>や体幹の屈曲や回旋を伴う作業は、腰痛の発生頻度を増加させると報告されている<sup>20)</sup>。今回、腰痛群では NRH 分類の四肢平均が有意に高値であり、ポリオの重症度は腰痛有訴率に影響を与える可能性が示唆された。また、ポリオ罹患患者では、運動神経麻痺や脚長差などに起因する左右非対称性が腰部へのストレスとなり、腰痛有訴率が高まっている可能性が考えられる。ポリオの左右非対称性と腰痛の関連については、今後、評価項目や症例数を増やして検討する必要がある。

ポリオ罹患患者の腰痛と ADL および QOL について、腰痛群は非腰痛群と比較して、BI, SF-36<sup>®</sup>-PCS が有意に低値であった。今回、直近 1 か月の腰痛に限定しており、痛みの強さが ADL および QOL に影響を与えたことが示唆された。また、腰痛群は PCS の無力感や GES が有意に低下しており、疼痛に加えて、破局的思考やそれに伴う自己効力感が、ADL ならびに QOL の低下につながったと推測される。複数の健常者における先行研究では、痛みの強さ<sup>21)</sup>や破局的思考などの心理社会的因子および恐怖心<sup>22)</sup>が ADL に影響することが知られており、今回ポリオ罹患患者でも同様の結果であった。

ポリオ罹患患者の腰痛の程度は、加齢により増大することが示唆された。佐藤ら<sup>23)</sup>は高齢者において加齢と抑うつスコアは運動器関連疼痛と正に相関すると報告しており、今回ポリオ罹患患者でも同様の傾向といえる。また本研究では、腰痛の程度と、GES、

表 2 群間比較の結果

		腰痛群 (n=25)	非腰痛群 (n=30)	p 値
年齢 (歳) <sup>a</sup>		68.7±5.5	67.4±5.2	0.371
性別 (男性/女性:人) <sup>b</sup>		8/17	14/16	0.407
側弯 (有/無:人) <sup>b</sup>		8/17	15/15	0.783
四肢 NRH 分類平均 <sup>c</sup>		3.0±0.7	2.4±0.7	0.005
BI (点) <sup>c</sup>		89.1±15.4	96.7±10.3	0.002
FAI (点) <sup>a</sup>		20.9±9.5	24.3±9.4	0.144
SF-36 <sup>®</sup> -PCS <sup>a</sup>		33.7±8.1	43.5±8.0	<0.001
SF-36 <sup>®</sup> -MCS <sup>a</sup>		50.9±11.0	52.0±9.9	0.692
HADS (点)	不安 <sup>c</sup>	4.7±3.3	4.3±3.3	0.739
	うつ <sup>a</sup>	5.1±2.4	4.7±3.2	0.625
PCS (点)	反芻 <sup>c</sup>	10.0±4.7	7.8±6.5	0.162
	無力感 <sup>c</sup>	7.2±4.3	4.5±4.7	0.028
	拡大視 <sup>c</sup>	4.8±2.6	3.7±3.5	0.114
	合計 <sup>c</sup>	22.1±10.5	16.0±14.0	0.055
GES <sup>c</sup>		29.3±17.6	47.9±22.7	0.001
運動習慣 (有/無:人) <sup>b</sup>		16/9	17/13	0.272
IPAQ	歩行 <sup>c</sup>	179.8±484.0	266.3±763.1	0.138
1 週間の活動量 (METs×分×日数)	中等度 <sup>c</sup>	52.8±196.8	69.9±161.2	0.243
	高強度 <sup>c</sup>	0.0±0.0	12.8±45.6	0.060
	総合 <sup>c</sup>	232.3±517.4	349.1±517.4	0.163
	座位 <sup>c</sup>	549.6±306.2	519.0±311.9	0.653

平均値±標準偏差, a: Student の t 検定, b:  $\chi^2$  検定, c: Wilcoxon の順位和検定.  
NRH: National Rehabilitation Hospital, BI: Barthel Index, FAI: Frenchay Activities Index, SF-36<sup>®</sup>: MOS Short Form 36-Item Health Survey, SF-36<sup>®</sup>-PCS: physical component summary, SF-36<sup>®</sup>-MCS: mental component summary, HADS: Hospital Anxiety and Depression Scale, PCS: Pain Catastrophizing Scale, GES: Gait Efficacy Scale, IPAQ: International Physical Activity Questionnaire, METs: metabolic equivalents

表 3 腰痛の程度と各評価項目との関連

項目		相関係数	p 値
年齢 <sup>a</sup>		0.399	0.011
四肢 NRH 分類平均 <sup>b</sup>		0.265	0.098
BI <sup>b</sup>		-0.395	0.012
FAI <sup>a</sup>		-0.340	0.032
SF36 <sup>®</sup> -PCS <sup>a</sup>		-0.594	0.000
PCS	無力感 <sup>b</sup>	0.401	0.010
GES <sup>b</sup>		-0.406	0.009
IPAQ	高強度 <sup>b</sup>	-0.352	0.026

a: Pearson の積率相関係数, b: Spearman の順位相関係数.  
略語は表 2 と同じ

PCS の無力感, IPAQ の高強度の相関を認めた.

近年, 腰痛の発生率や遷延化に対して, ストレスや不安, 抑うつ, 恐怖-回避など種々心理社会的因子が影響されると報告される<sup>24)</sup>. ポリオ罹患においても, 自己効力感の低下, 破局的思考の増大, 活動量の低下は相互に影響して腰痛増強の悪循環を引き起こし, 腰痛の間接的リスクとなっている可能性がある. 健常者においてエアロビック運動やアイソメトリック運動により運動部以外でも鎮痛効果を認め, 運動時間や強度に依存すると報告されており<sup>25)</sup>, ポリオ罹患においても適度な運動は腰痛改善に有用かもしれない.

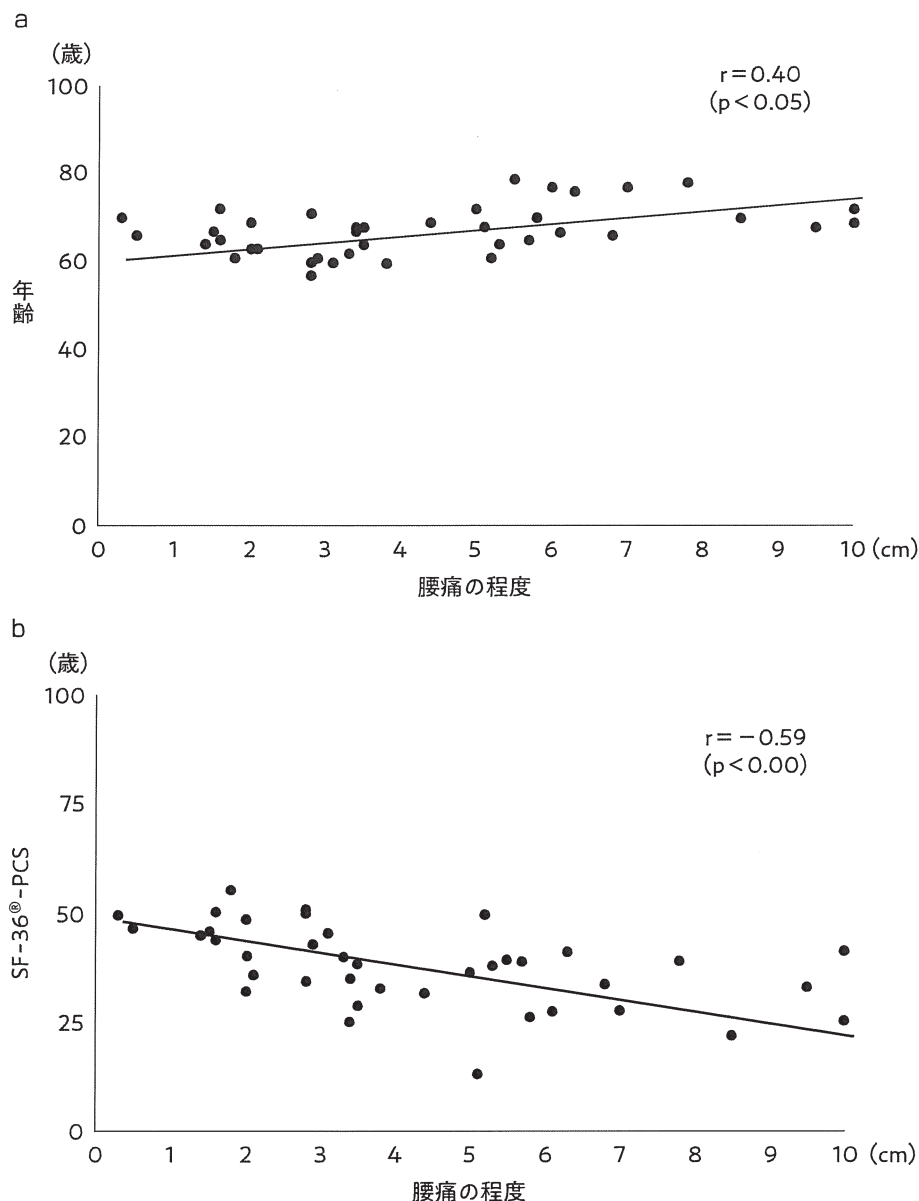


図 腰痛の程度との関連

a：腰痛の程度と年齢の相関，b：腰痛の程度と SF-36<sup>®</sup>-PCS の相関。

SF-36<sup>®</sup>-PCS：Mos Short Form 36-Item Health Survey Physical Component Summary

本研究の限界はいくつかある。まず、今回の評価は、自記式の間診票が中心となっていることである。特に腰痛に関しては、診察や X 線などの画像所見を用いていないため、原因の医学的診断がなされておらず、非特異的腰痛や心因性疼痛などが混在している可能性がある。また、ポリオ罹患者が PPS を併発しているか否かは診断できていない。次に、本研究は横断調査であるため、腰痛と各評価結果との因果関係は明らかでない。今後は、縦断研究により腰痛と破局的思考など心理社会的因子や活動量、自

己効力との因果関係を明確にし、加えて、運動療法を含む介入が腰痛軽減に有効か検証する必要がある。

腰痛は、身体機能、ADL および QOL の低下、勤労者では生産性低下につながることから、予防が重要である。今回、ポリオ罹患患者では腰痛有訴率が高く、ADL および QOL、心理社会的因子、歩行に関する自己効力感、身体活動量に影響を与えることが明らかとなった。本研究の結果から、身体機能に加えて、破局的思考や自己効力感など心理社会的因子を考慮した多面的な介入が、腰痛の予防や改善に有



効な可能性が考えられる。また、早期加齢変化モデルとしても有用な可能性があり、今後高齢者の腰痛にも応用していきたい。

## 結語

今回、ポリオ罹患患者における腰痛の有訴率を調査し、腰痛の有無、程度が与える影響について検討した。ポリオ罹患患者における腰痛有訴率は、健常高齢者よりも高値であった。また、腰痛群では、ADLおよびQOL、自己効力感が低下し、破局的思考が増大した。自己効力感の低下、破局的思考の増大と活動量の低下は、腰痛の悪循環を引き起こす可能性が示唆された。今後、ポリオ罹患患者の腰痛予防や運動療法を含む介入の効果を検討したい。

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## 【別紙資料18】

### 令和 6 年度ポリオ検診（第 24 回）結果の概要

この度は、令和 6 年度ポリオ検診にご参加いただきありがとうございます。2001 年に開始したポリオ検診は 24 回目を迎えました。2020～2023 年は、新型コロナウイルス感染症の影響でオンラインや郵送による実施でしたが、今年はおかげさまで現地開催を再開することができました。

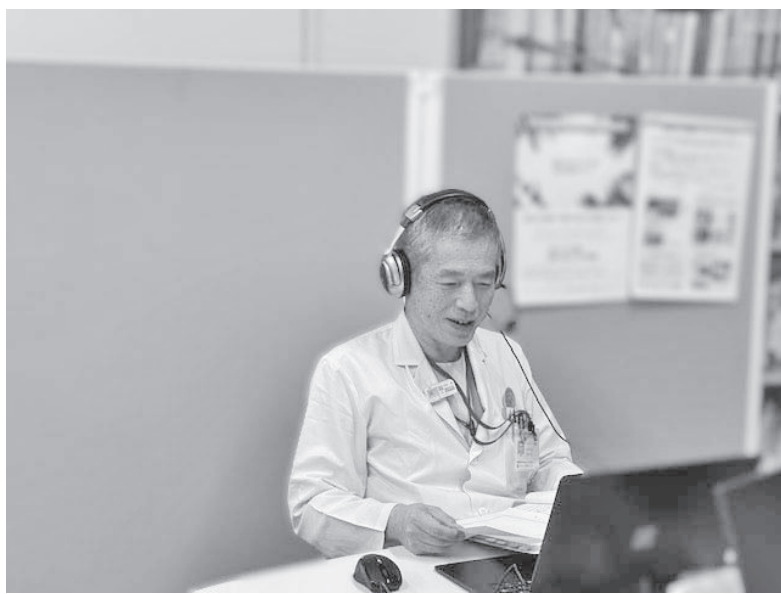
また皆さまの現状により合う検診としてお役に立てるよう、今年度は、体成分分析 Inbody、嚥下（飲み込み）機能に関わる舌圧、身体活動量計測後の対面指導（対象者限定）など、新しい試みを取り入れました。また安全な検診のため、転倒リスクがある歩行テストは削除し、関節可動域・筋力・Inbody は、参加者が計測台にスタンバイしたらスタッフが巡回して計測することで参加者の移動負担を軽減しました。久しぶりの現地開催で、至らない点が多々あったかと存じます。お気づきの点、感想などありましたら、お気軽にお寄せください。

今回の問診の集計が完了いたしましたので、結果の概要を報告させていただきます。各参加者の結果は、個別の検診報告書をご覧ください。来年度もポリオ検診で皆さまにお目にかかれることを楽しみにしています。

● 今回はポリオの既往のある 48 名の方が参加されました。内訳は男性 18 名、女性 30 名、平均年齢は 71.5±6.3 歳でした。また、そのうち現地検診参加（36 名）、リモート相談参加（11 名）、活動量計測のみ参加（1 名）でした。



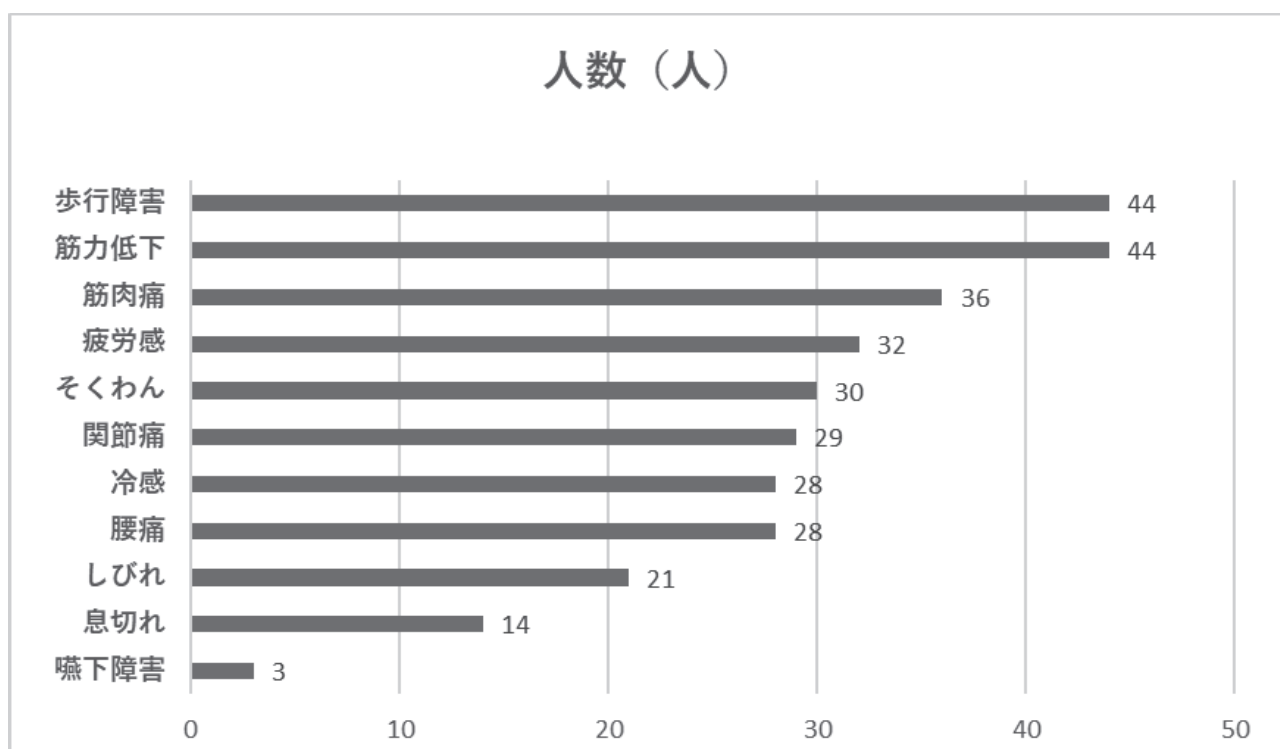
【現地検診の様子】



【オンライン検診の様子】

● 参加者 48 名の現在の自覚症状に対する問診では、90%以上の方が歩行障害、歩行障害、60%以上の方が筋肉痛、疲労感、側弯、関節痛、50%以上の方が冷感、腰痛の症状を自覚されていました。

上記の症状の多くはいわゆるポストポリオ症候群の診断基準に含まれるものですが、これらの症状は通常に加齢現象や整形疾患、神経疾患でも生じる可能性があるため、診断には他の原因疾患がないかを調べる必要があります。該当する項目の多い方は精密検査をお勧めいたします。



§ 今回記入していただいたアンケートではバーサルインデックス、FAI、SDL、SF - 8、CIQ-R という 5 つの指標の評価を行いました。以下、全体的な結果をご報告いたします。

● **バーサルインデックス (Berthel Index)** とは日常生活を行う能力を評価する尺度です。今回参加された方々の平均点は  $92.9 \pm 11.4$  点（100 点満点）と高得点であり、麻痺がありながらも身の回りのことはほぼ自立されている方が多いようです。

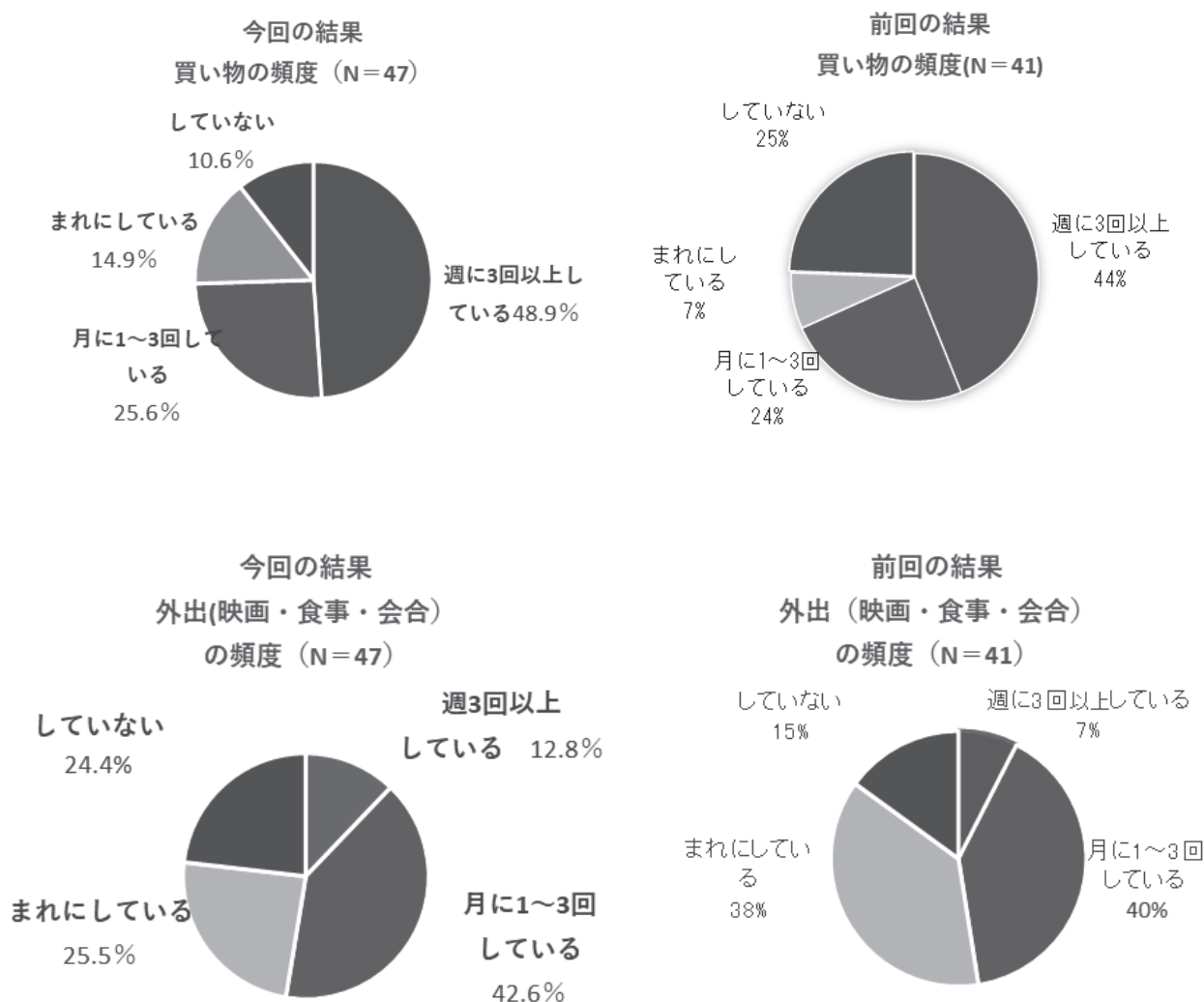
● **FAI(Frenchay Activities Index)** とは家事や趣味、仕事等をどのくらい行っているかという毎日の生活習慣（ライフスタイル）を表す指標で、日本人では女性よりも男性で低い傾向があります。今回参加された方の平均は  $21.1 \pm 9.27$  点（45 点満点）で、性別では、男性  $16.4 \pm 9.17$  点、女性  $23.8 \pm 8.39$  点でした（在宅で家族と同居している重大な疾病や障

害のない方の平均値は、男性 26.8 点、女性 34.6 点です）。

参考までに、前回令和 5 年度のポリオ検診の参加者の FAI の平均は  $22.0 \pm 10.5$  点、男性  $16.3 \pm 11.3$  点、女性  $23.7 \pm 11.2$  点でした。2020 年～2022 年は低水準で新型コロナウイルス感染症流行の影響が疑われましたが、昨年は回復傾向となり、今年も概ね同様です。

次に、主要な項目を円グラフで示します。

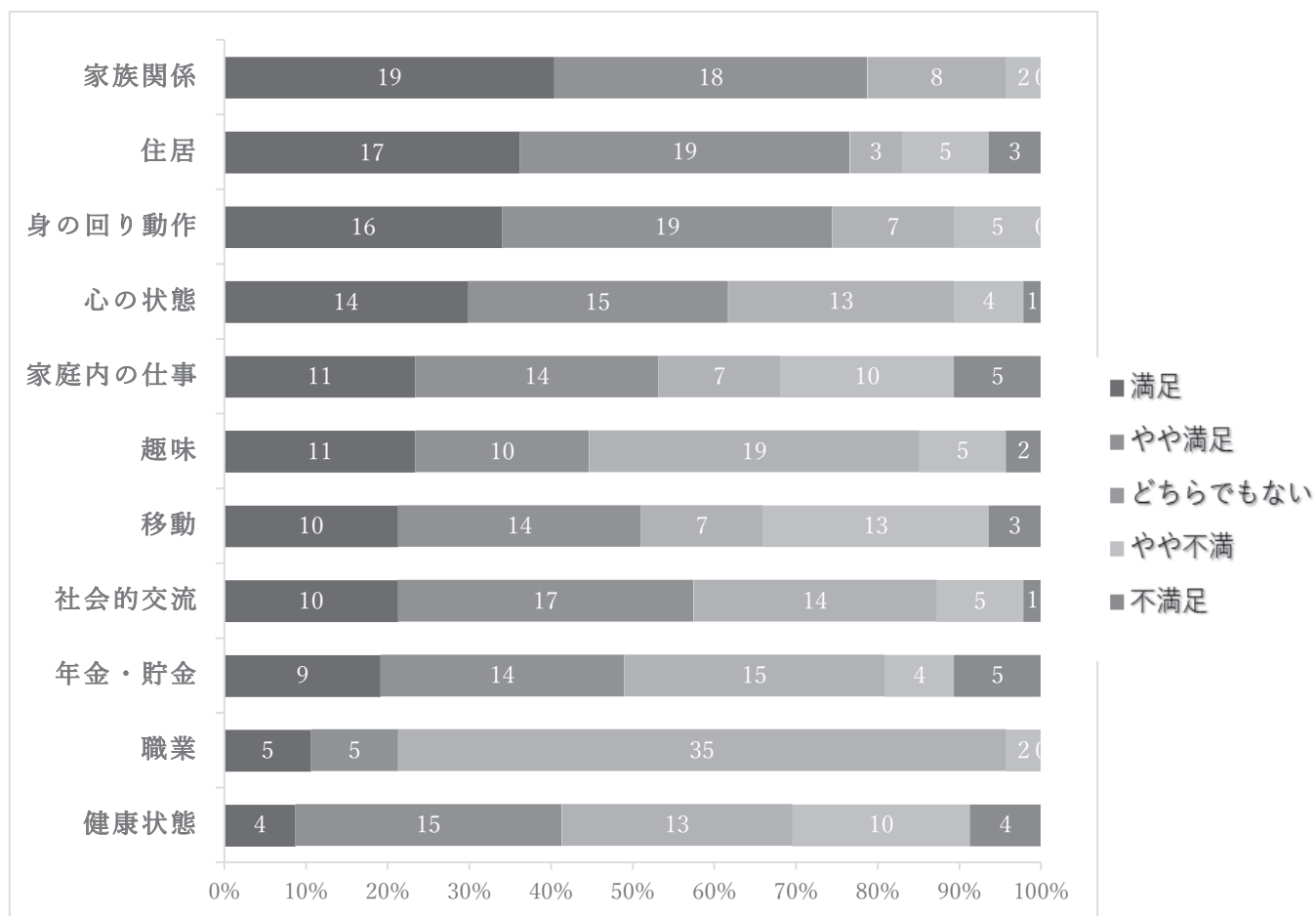
比較のために、左に今回の結果、右に前回令和 5 年度の結果を示します。



買い物に関しては「週に 3 回以上」「月に 1～3 回している」の 2 項目で全体の 75%と保たれていました。また、外出に関しては、「週 3 回以上している」「月に 1～3 回している」の割合がやや増加していますが、一方で「していない」の割合も増えています。積極的に外出している方と、さまざまな理由で外出しない（できない）方が、二極化しつつあるのかもしれない。

● **SDL** とは健康や日常生活の満足度を表すという指標で、今回参加された方の平均は 36.5±8.0 点（55 点満点）でした。次のグラフにその詳細を示します。前回令和 5 年度の参加者の平均は 38.3±7.0 点でした。

新型コロナウイルス感染症の流行期には低下傾向でしたが、令和 4～5 年度にコロナ前の水準まで回復し、令和 6 年度も概ね維持されています。次のグラフにその詳細を示します。項目によって満足している方が多いもの（家族関係、住居、身の回りの動作、心の状態、社会的交流など）と、不満足・やや不満足である方が多いもの（家庭内の仕事、移動、健康状態など）があります。



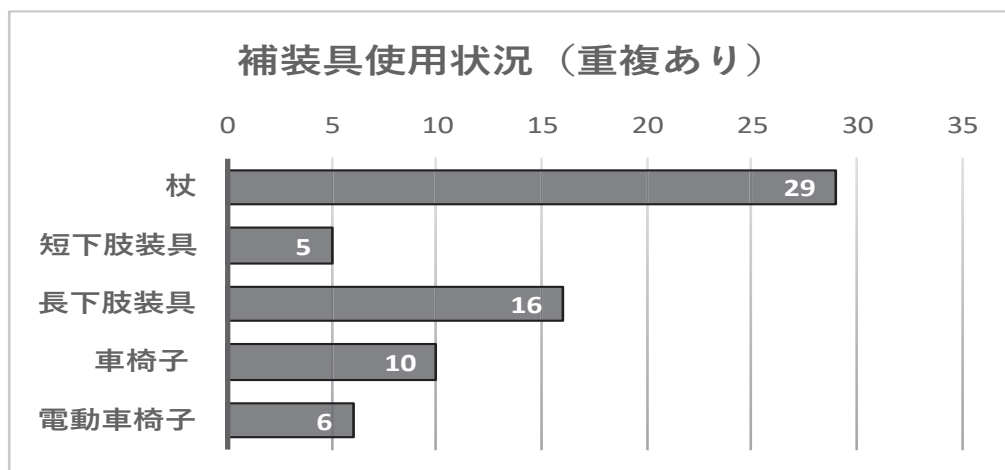
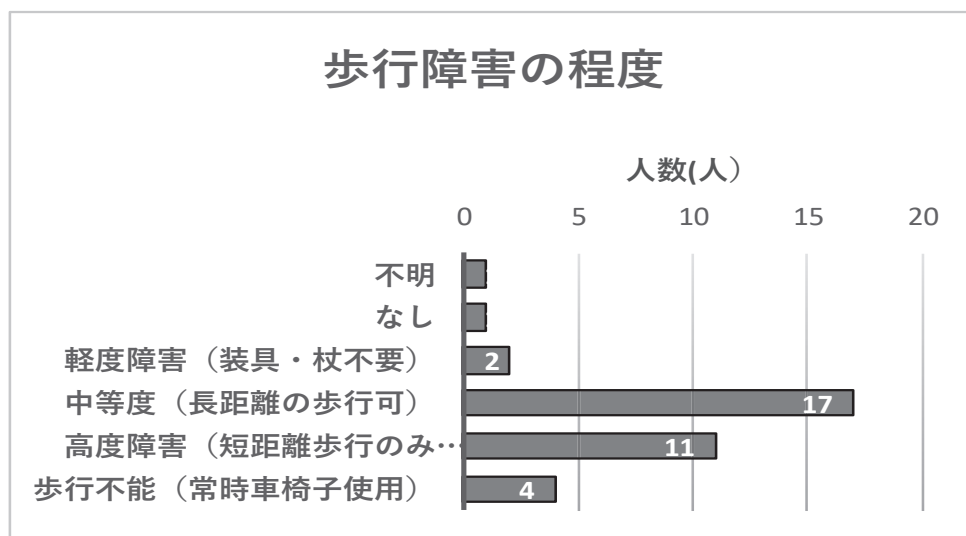
● **SF-8 (Short Form 8)** とは健康関連の QOL(Quality of Life : 生活の質)を評価する尺度です。その数値は偏差値のように 50 を基準に評価します。今回の調査では身体のコアの平均値は 41.2±7.7、精神的総合スコアの平均値は 51.1±6.3 でした。例年同様、身体的な生活の質の低下は認められますが、日々の中で精神的な生活の質を良好に維持している傾向が伺われます。

●**CIQ-R (Community Integration Questionnaire-Revised)** とは仕事やボランティア活動などの社会活動の状況を表す指標で、今回参加された方の平均値は 18.2±6.5 点（35 点満点）でした。今回、現代に合わせて質問内容が改訂された最新版を使用しました（現時点では一般的な平均値データはありません）。

●次のグラフは、現地検診参加者（36 名中 35 名）の歩行障害の程度と補装具の使用状況に関する結果です。

歩行障害の程度は、「歩行障害なし」から「長距離歩行が可能」な中等度の障害までの方は合計 20 名、「短距離のみ可」から「常時車椅子使用」の高度障害のある方は合計 15 名でした。

装具や車椅子の使用状況（重複あり）については、杖を使用している方が約 82.9%、大腿まである長い装具（長下肢装具）を使用されている方が約 45.7%、膝から下の短い装具（短下肢装具）を使用されている方が 14.2%いらっしゃいました。車椅子を使用している方が約 28.5%、電動車椅子を使用している方が約 17.1%という結果でした。





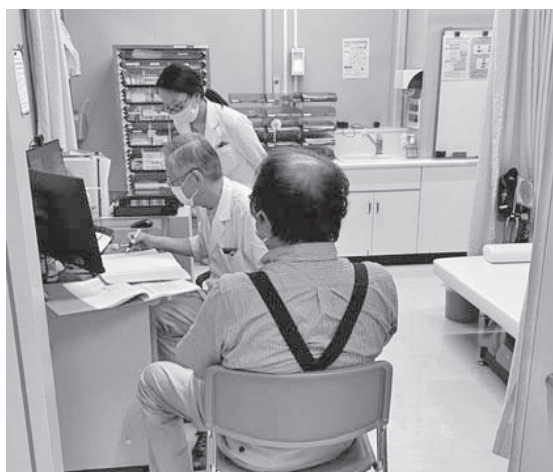
ポリオに罹患された方々は、下肢麻痺によって歩行に何らかの障害をきたしていることが多く、今回も「杖と装具（短下肢あるいは長下肢装具）」を組み合わせで使用している方が多くいらっしゃいました。さらに、車椅子や電動車椅子を組み合わせで使用されている方もおられます。

近年、ポリオによる麻痺だけでなく加齢による影響も加わって、ポリオの方が抱える障害は複雑化しています。ポリオ検診は、新たな筋力低下を生じさせない、また悪化の徴候を早期に掴み、適切な対応に役立ちます。今回のポリオ検診を契機に、外来受診や検査入院につながったり、新しい装具を作製した参加者の方も数名いらっしゃいます。

今回のポリオ検診の結果を、皆さまの健康管理にお役立ていただければ幸いです。

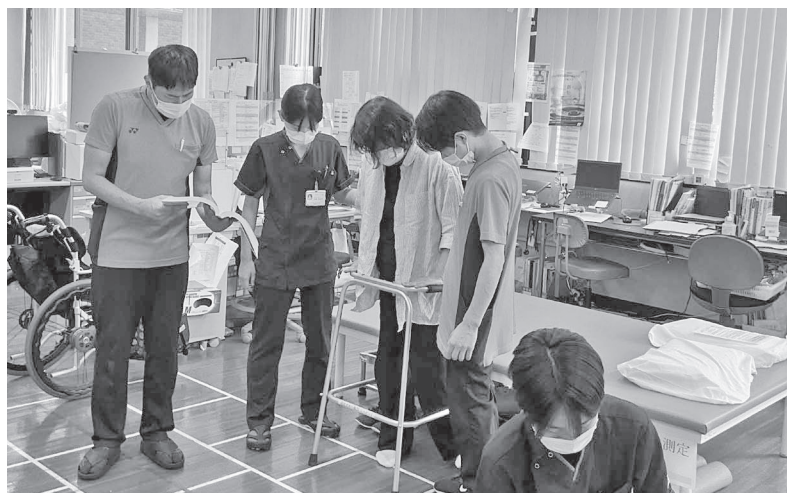
（文責：蜂須賀明子）

### 【現地検診写真集】

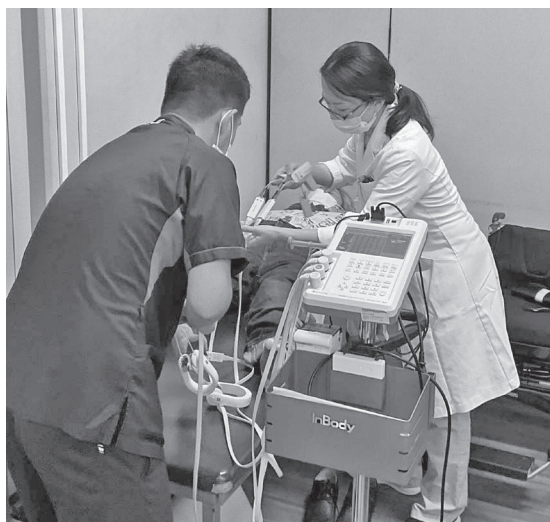


〔身体活動量計測後の対面指導の様子〕





〔関節可動域・筋力測定の様子〕



〔体成分分析 Inbody の様子〕





〔舌圧測定の様子〕



〔呼吸器測定の様子〕

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# ポリオ罹患者のかかりつけ医としての包括的リハビリテーション診療

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**Key Words** ポストポリオ症候群 過用 高齢化 加齢 カーボン製長下肢装具

## 内容のポイント Q&A

**Q1** かかりつけ医としての診察のポイントは？  
病歴を丁寧に聴取し、日頃の身体所見を把握しておくことは、正確な診断や今後のリハビリテーション治療に役立つ。特に加齢性変化や二次障害を生じると、もともとポリオによる弛緩性麻痺がある状態に、新たな筋力低下や関節痛等が加わり、症状の新旧の判断が難しくなる。発症時を含む病歴の聴取、筋萎縮、側弯、脚長差、筋力、関節可動域、立位歩行の評価、基本的日常生活活動として Barthel Index の評価を行う。

**Q2** 機能維持のためのポイントは？  
ポリオ罹患者の高齢化が進み、ポリオに伴う障害と加齢性変化への対応が必要である。具体的には、低負荷高頻度を基本とする運動療法、装具を含む歩行補助具や車椅子の適切な使用、過負荷や廃用を避ける生活指導が中心となる。これまでの医療保険や障害福祉サービスだけでなく、高齢化に伴い、介護保険による通所・訪問リハビリテーション、杖や歩行器、車椅子のレンタル、住宅改修、訪問介護等を活用できるケースが増えている。

**Q3** 注意すべき二次障害とその対応は？  
ポリオ罹患者において注意すべき二次障害として、ポストポリオ症候群 (PPS) が重要である。ポリオに罹患後、ある程度まで機能的に回復し、安定した期間を経て、新たな筋力低下や筋萎縮を主症状として、易疲労性、疼痛等、さまざまな障害を生じる病態である。PPS の対応は、ポリオ罹患者の機能維持と同様、運動療法、装具を含む歩行補助具や車椅子使用、生活指導が中心となる。PPS では特に過負荷に注意する。

**Q4** かかりつけ医として知っておきべき薬物管理・医学的管理は？  
現在、ポリオ罹患者に特異的な治療薬はない。適度な運動 (活動) を指導し、負荷量の目安は疲労感や筋肉痛が翌日に残らない程度、血液検査で横紋筋融解を示唆する CK 値も 1 つの指標とする。その他、ポリオ罹患者の現状評価として、X 線単純撮影、骨格筋 CT、骨塩定量、肺機能、睡眠時無呼吸検査等を行う。新たな筋力低下等、PPS を疑う際は、針筋電図や装具療法等を検討し、自院で対応が難しい場合は専門医へ紹介する。

## Comprehensive Rehabilitation Care as a Primary Care Physician for Polio Survivors

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## はじめに

ポリオウイルス（エンテロウイルス属）の90～95%は不顕性感染であるが、ごく一部が中枢神経へ感染していわゆるポリオ（急性灰白髄炎）を生じる。典型的なポリオは、脊髄前角細胞障害により四肢の弛緩性麻痺を呈し、小児期に発症が多く脊髄性小児麻痺（小児麻痺）ともよばれる。急性期のポリオは高熱等、感冒様症状ののち、急速に進行する非対称性の重度弛緩性麻痺が出現する。その後、正常または部分的に障害を受けた前角細胞の神経再支配により筋力が回復して、一定程度の弛緩性麻痺が残存する。

わが国では、1940年代後半から1960年初頭にポリオが大流行したが、1961年の経口生ワクチン導入により終息した<sup>1)</sup>。1981年以降は野生株ポリオウイルスによるポリオはないが、経口生ワクチン副反応として接種者やその接触者にワクチン関連麻痺（vaccine-associated paralytic poliomyelitis；VAPP）が生じ（200万接種あたり1例<sup>2)</sup>）、わが国の重大な問題であった。VAPP予防のため、わが国では2012年9月に不活化ワクチン（注射）へ切り替えられ定期接種が継続されている<sup>1)</sup>。

## かかりつけ医としての診察のポイント

かかりつけ医として、ポリオ罹患者の病歴を聴取し、日頃の身体所見を把握しておくことは、正確な診断や今後のリハビリテーション治療に役立つ。特に加齢性変化や二次障害を生じると、もともとポリオによる弛緩性麻痺がある状態に、新たな筋力低下や関節痛等が加わり、しばしば症状の新旧の判断が難しくなる。

### (1) 病歴

「発症様式（発症時期、高熱後の麻痺）」は他疾患の鑑別に役立つ。幼少期から筋力低下や筋萎縮を認める病態として、分娩麻痺（腕神経叢損傷）、脳性麻痺等がある。感覚障害の有無や中枢性と末梢性等、病態やその対応が異なるが、ときに混同されており注意する。「現在の麻痺肢」とともに、「発症時の麻痺の分布」を確認することは、新しい筋

力低下や潜在的な神経障害の可能性を把握するのに役立つ。幼少期の本人は覚えていないケースが多く、家族から聞いている「高熱後に歩けなくなった」「ハイハイができなかった」「ずり這いはできていた」「玩具で遊びができなくなった」等のエピソードが参考になる。たとえば、現在は左下肢麻痺のポリオ罹患者が、発症時は両下肢麻痺であれば、右下肢は潜在的な障害の可能性があり注意深く観察する。

### (2) 診察

筋萎縮、側弯、脚長差、筋力、主関節の関節可動域を測定し、立位・歩行を評価する。左右差を伴う殿部の筋萎縮や側弯は、座位の体幹の傾きや腰痛の原因となる。脚長差は、歩行時の体幹動揺を呈し、二次的に両側の足・膝・股関節の負担増加へつながることがある。筋力では、特に大腿四頭筋と殿筋群（大殿筋、中殿筋）は起立・歩行に重要である。大腿四頭筋の筋力低下は、膝折れや転倒のリスク因子となる。ポリオ罹患者63名（うちPPS 61名）における5年間の検討では、90%で経年的な膝伸展筋群の筋力低下を生じている<sup>3)</sup>。また、殿筋群（大殿筋、中殿筋）は、特に大腿四頭筋の筋力低下が目立つポリオ罹患者において、起立・歩行への寄与が大きく、その筋力低下は起立困難や歩行時の立脚後期の股関節伸展不良、立脚期の体幹の患側への傾きが生じる。関節可動域では、特に膝関節の伸展制限や過伸展、足関節の固定術後の拘縮等の可動域制限は、歩行や装具療法を考える際に重要となる。ポリオは感覚障害を伴わない。感覚障害があれば他疾患の鑑別を要する。

### (3) ADLとQOL

基本的日常生活活動はBarthel Index (BI)、応用的日常生活活動Frenchay Activities Index (FAI)、参加制約はCommunity Integration Questionnaire (CIQ)、全般的な健康関連QOL (quality of life) はMOS Short-Form 36 Item Health Survey (SF-36) やSF-8等を用いる<sup>4)</sup>。ポリオ罹患者のQOLは、身体的健康は健常者より低いものの、機能障害への長年の対処と適応により、精神的健康は維持されることが多い<sup>5)</sup>。



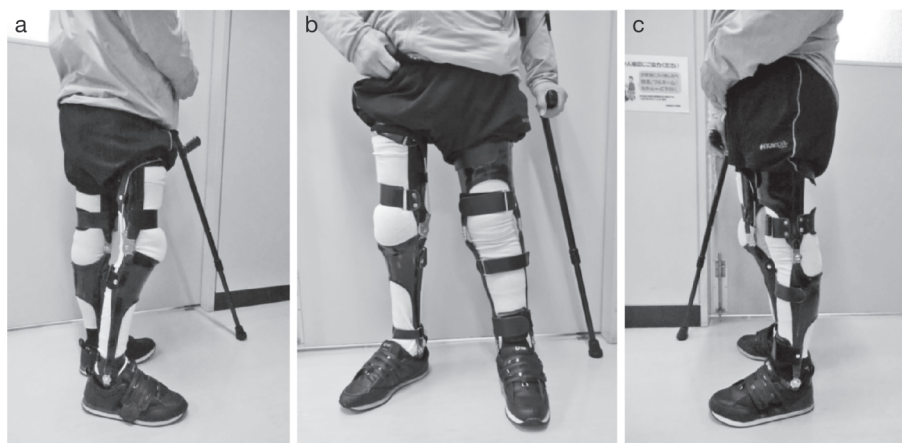


図1 ポリオ罹患者の両長下肢装具

- a: 図1bの右側面像。膝折れに対して、カーボン製長下肢装具〔ウェッジロック膝継手(ストッパー付き輪留め式)、遊動足継手、大腿カフ(カーボン後面)、Pretibial shellタイプ)を使用。  
b: ポリオによる両下肢弛緩性麻痺に対して両長下肢装具を使用している。  
c: 図1bの左側面像。反張膝に対して、カーボン製長下肢装具〔オフセット膝継手、遊動足継手、大腿カフ(カーボン前面)、下腿カフ(カーボン後面)]を使用。

## 機能維持のためのポイント

ポリオ罹患者の機能維持には、ポリオに伴う障害と加齢性変化への対応が必要である。2022年に行われたポリオ罹患者598人の回答による全国ポリオ会連絡会のアンケート<sup>6)</sup>でも、平均年齢70.1歳と高齢化が進んでいる。同アンケートでは、「生活面等での不安」は76.3%が「ある」と回答し、その具体的な内容(複数回答)は、「障害」「高齢化」がそれぞれ81.8%、74.3%と高く、次点を大きく引き離す結果であった。

具体的な機能維持の方法は、運動療法、装具を含む歩行補助具や車椅子使用、生活指導が中心となる。これまでポリオ罹患者が自分で工夫したり、医療保険や障害福祉サービスを活用していたりしたところ、高齢化に伴い65歳以上では新たに介護保険サービスを利用できる。介護保険サービスは、原則、障害福祉サービスよりも優先される。

### (1) 運動療法

体力を維持するため適度な運動(活動)は重要である。ポリオでは、神経筋疾患における過用性筋力低下<sup>7,8)</sup>を避けるために「低負荷高頻度」の運動が基本となる。運動負荷設定は、疲労感や筋肉

痛が翌日に残らない程度、採血で横紋筋融解を反映するCK(creatine kinase)値が上昇しない範囲<sup>9)</sup>が目安となる。これまでは家事や仕事で活動量を確保できていた人も、近年は加齢に伴う体力低下や退職により活動量が減少していることが多い。新たな運動習慣として、65歳以上であれば、介護保険サービスのデイケア(通所リハビリテーション)や訪問リハビリテーションは、比較的安全に運動を継続することができる。その際、前述の低負荷高頻度の運動を基本とすること、個々の障害に応じた具体的な注意点(たとえば、麻痺肢に対して負荷をかけるマシントレーニングは避けて、セティングや自重による筋力強化を推奨する等)を情報提供できるとよい。

### (2) 装具を含む歩行補助具や車椅子の使用

関節変形や膝折れ等に伴い転倒や歩行障害があれば、装具を含む歩行補助具や車椅子の使用を検討する。

装具療法は、足部変形や脚長差に対して足底装具や靴型装具、下垂足に対して短下肢装具、反張膝に対して膝装具やオフセット膝継手の長下肢装具(図1b, c)、膝折れに対して軽量で適合に優れたカーボン製長下肢装具(図1a, b)<sup>10)</sup>等を処方する。近年では、軽度～中等度のポリオ罹患者が、高齢

表 1 PPS 診断基準 (Halstead)

- (1) 麻痺性ポリオの確実な既往
- (2) 部分的または完全な神経学的・機能的回復
- (3) 少なくとも 15 年間の神経学的・機能的安定期間
- (4) 安定期間を経過した後に、以下の健康問題が 2 つ以上発生
  - ・ 普通でない疲労
  - ・ 関節痛/筋肉痛
  - ・ 麻痺側または非麻痺側の新たな筋力低下
  - ・ 機能低下
  - ・ 寒冷に対する耐性の低下
  - ・ 新たな筋萎縮
- (5) 以上の健康問題を説明する他の医学的診断がない

(Halstead et al, 1987, 文献 12 を基に作成, 一部改変)

表 2 PPS 診断基準 (March of Dimes)

- (1) 運動ニューロン消失を伴う麻痺性ポリオの既往 (病歴: 急性発症した麻痺性疾患, 診察: 筋力低下や筋萎縮の後遺症, 筋電図: 脱神経所見).
- (2) 急性ポリオを発症し, 部分的にあるいは完全な機能回復後に, 神経学的に機能が安定した状態が一定期間 (通常 15 年以上) あり.
- (3) 進行性で持続する新たな筋力低下や易疲労性 (持久力減少) が徐々に, あるいは突然出現する. 全身性疲労, 筋萎縮, 筋や関節痛を伴うことがある. PPS 関連症状として, まれに, 新たな呼吸や嚥下の問題を生じる.
- (4) これらの症状は 1 年以上持続する.
- (5) 同様の症状の原因となる他の神経疾患, 内科疾患, 整形外科疾患を除外する.

(Gonzalez et al, 2010, 文献 13 を基に作成, 一部改変)

化に伴い歩行障害が顕在化し, 初めて足底装具や短下肢装具を作製したり, 重度のポリオ罹患者が, 重度麻痺肢に長下肢装具を使用中に, 対側下肢の筋力低下が進行し, 新規に対側の膝装具や短下肢装具を作製したりすることが増えている. ポリオ罹患患者における装具療法のポイントとして, ①残存する機能を妨げない, ②患者の希望を優先する, ③脚長差補正は 1/3 より開始して数年かけて 2/3 程度とする, ④初回装具作製時の仮合わせ (特にカーボン製長下肢装具の仮装具) では, 十分に慣れる期間 (約 1 カ月) を設けて適宜微調整する.

T 字杖やロフトストランド杖等の歩行補助具や電動車椅子を含む車椅子は, 従来使用している人だけでなく, 高齢化に伴い新しく導入するケースが増えている. 中年期までは障害者福祉サービスの補装具支給が中心であったが, 65 歳以上になると, 介護保険のレンタルが優先となる. 特に車椅子は, 介護保険のほうを利用できる対象者が広がる. 一方で, 障害により個別性が高いオーダーメイドが必要な場合は, 補装具支給制度を利用できる.

### (3) 生活スタイルの再構築

ポリオ罹患患者は勤勉家で手を抜かない「頑張り気質」<sup>11)</sup>が知られ, 後述するポストポリオ症候群 (post-polio syndrome: PPS) の誘因となることがある. そのため, 病態を十分に説明し, 無理をしない生活スタイルへの変更は“病気に対する治療戦略”であると理解してもらう. 和式から洋式へ生活様式の変更 (床生活から椅子生活, 布団からベッド), 手すりや台を設置する環境整備, 身

体介護や生活援助サービス等訪問介護の導入等, 日常生活における負荷の軽減は重要である. その他, 食器洗い乾燥機や乾燥機付き全自動洗濯機等の利用で家事負担を軽減することも有効なことがある.

## 注意すべき二次障害とその対応

### (1) ポストポリオ症候群 (PPS)

注意すべき二次障害として, PPS が重要である. ポリオに罹患後, ある程度まで機能的に回復し, 安定した状態が続いたのち, 新たな筋力低下や筋萎縮を主症状として, 易疲労性, 疼痛等, さまざまな障害を生じる病態である<sup>12,13)</sup>. PPS の発症率は, 母集団や診断基準で異なり, 北九州市で身体障害者手帳に基づき Halstead の診断基準を用いた疫学調査では PPS 発症率は 75% と報告される<sup>14)</sup>. PPS の病因は明確でないが, 誘因として加齢, 過用, 廃用, 体重増加等が挙げられ, 発症メカニズムは運動単位の変性や減少と考えられる<sup>8)</sup>.

### (2) PPS の診断

PPS には 2 つの診断基準がある. Halstead の診断基準 (1987 年) (表 1)<sup>12)</sup> は最も広く用いられるが, 関節痛や冷感等, 筋症状ではない主観的項目が中心で, 日常臨床では症状の判断に苦慮することもある. March of Dimes 国際会議の診断基準 (2010 年) (表 2)<sup>13,15)</sup> は近年用いられることが増えており, 筋力低下等, 筋所見を主体として筋電図による客観的項目も含み, 臨床的に優れている.

表3 NRH ポリオ後肢体分類と運動プログラム

NRH	強度		頻度	1回の運動時間	運動ペース	目標
<b>Class I</b> No clinical polio	最大心拍数 60~80%	6~9 METs	週3~5日	15~30分	—	筋力増強、心耐久性向上
<b>Class II</b> Subclinical polio	最大心拍数 60~80%	5~7 METs	週3~4日、 隔日	15~30分	4~5分運動+1分休憩	適度な筋力向上(障害筋)、 筋力維持(正常筋)
<b>Class III</b> Clinically stable polio	—	4~5 METs	週3~4日、 隔日	15~20分	2~3分運動+1分休憩	筋力維持(障害筋)、 可能な場合は筋力向上
<b>Class IV</b> Clinically unstable polio	—	≤3 METs	週2~3日、 隔日	10~15分	2~3分運動+1~2分休憩	筋力低下進行の予防 (障害筋)
<b>Class V</b> Severely atrophic polio	日常生活の活動 (装具や車椅子が必要)		—	—	—	(関節可動域の維持)

※四肢のNRH分類が異なる場合、運動プログラムに使用する肢体で最も障害が高度なものを基準に、運動プログラムを処方する。

(たとえば、歩行では右下肢および左下肢、座位での上肢エルゴメーター駆動では右上肢および左上肢のNRH分類に基づき判断する。)

※新たな筋力低下、疼痛、疲労感が出現したら、運動療法の縮小や中止、装具使用等を検討する。

(Halstead et al, 1996, 文献18を基に作成、一部改変)

臨床診断では、安定期に可能であった動作と、新しく困難になった動作を病歴聴取することで、「新しい筋力低下」部位を同定する。独歩可能であったものが、右下肢で膝折れしやすくなった場合、右大腿四頭筋の新しい筋力低下が疑われる。新たな筋力低下の鑑別疾患として、絞扼性ニューロパチー(杖・松葉杖使用による手根管症候群や橈骨神経麻痺)や変形性脊椎症に伴う脊髄症や神経根症は、臨床的に頻度が高い。

神経伝導検査や針筋電図は、下位運動ニューロン機能の判定や他疾患の鑑別目的に有用である。針筋電図では、慢性神経原性変化(ポリオ既往)の特徴として、持続の長い高振幅MUP(motor unit potential)や遅延動員、時に多相性MUPがみられる。また活動性脱神経所見(新たな筋力低下)として、線維自発電位や陽性鋭波が出現する。F波は、出現率低下や反復F波(同一の潜時・振幅・波形)を認めることがあり、運動単位数減少との関連が示唆される<sup>16)</sup>。

### (3) PPSの治療

PPSの治療法として確立したものではなく、その発症予防が第一である。すなわち、ポリオ罹患者の機能維持(前述)と基本的に同様な対応で、運動療法、装具を含む歩行補助具や車椅子使用、生活指導が中心となる。特にPPSでは、過用性筋

力低下を生じるリスクが高く、運動療法における難しさがある。PPSの安全で適切な運動療法のため、病歴、身体所見、筋電図を組み合わせたNRH(National Rehabilitation Hospital)ポリオ後肢体分類(NRH分類)と運動プログラムが提唱される<sup>17,18)</sup>(表3、図2)。NRH分類の原法どおりではなくても、多面的に病態をとらえる本概念は、PPSへの対応を考える際に役立つ。

### (4) PPSの予防とポリオ検診

各地の大学病院診療科と患者会の共同で、PPS等、二次障害の予防や障害管理を目的としたポリオ検診が実施されている<sup>4,19)</sup>。ポリオの患者会は全国各地にあり、会員相互の交流、情報交換や障害に対するピアカウンセリング等、支援活動を行っている。2022年に実施された患者会による全国規模のアンケート結果は、令和時代のポリオの状況がよくわかり、当事者のみならず医療者にとっても大変参考になる<sup>6)</sup>。

### かかりつけ医として知っておきべき 薬物管理・医学的管理

かかりつけ医は、日頃の身体状況を把握し、ポリオに伴う障害と加齢性変化に対して、医学的管理を行う。血液検査は通常は正常範囲であるが、CK値は過用に伴う横紋筋融解を示唆して上昇す



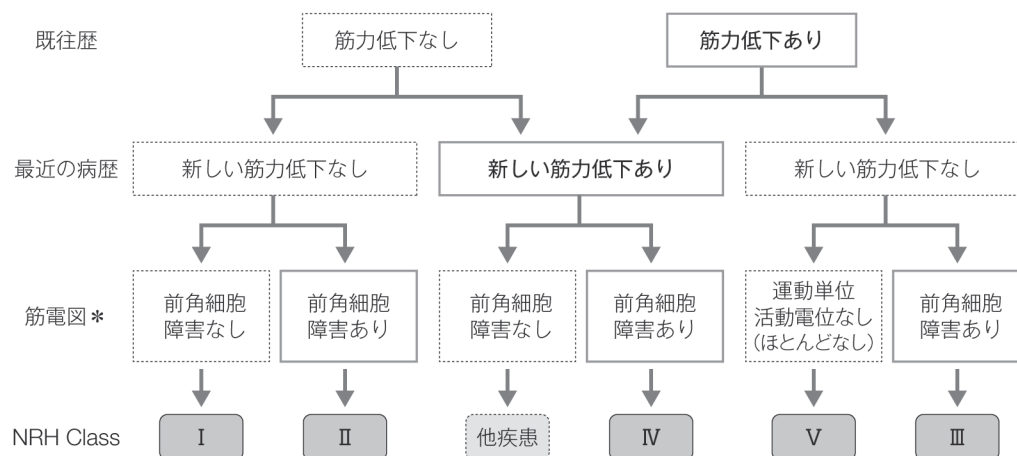


図2 NRH ポリオ後肢体分類のアルゴリズム

\*各肢3カ所以上で実施

上肢：上腕二頭筋，上腕三頭筋，第一背側骨間筋または短母指外転筋

下肢：大腿四頭筋，前脛骨筋，腓腹筋

(Halstead et al, 1996, 文献18を基に作成，一部改変)

ることがあり，その際は過負荷を避けるよう指導する．また，骨関節の変形性変化を判定する目的で四肢体幹のX線単純撮影，四肢体幹筋の萎縮や脂肪変性を判定する目的で骨格筋CT，特に麻痺肢は骨密度が低下しやすく両大腿骨頸部を含む骨粗鬆症の判定のため骨塩定量，球麻痺や体幹麻痺の呼吸への影響を判定する目的で肺機能検査や睡眠時無呼吸検査を行う．新たな筋力低下等，PPSを疑う際は，針筋電図や装具療法等を検討し，自院で対応が難しい場合には専門施設へ紹介する．

ポリオ罹患者に特異的な治療薬はない．エビデンスは確立していないものの，前角細胞を含む末梢神経障害の回復を期待してビタミンB12製剤が処方されることがある．また末梢神経障害による手足のつり症状があれば，症状緩和のために芍薬甘草湯は有効である．骨粗鬆症があれば骨折予防のため骨粗鬆症治療薬の導入を検討する．

日本リハビリテーション医学会の活動として医療者向けのPPS診療ガイドンス<sup>19)</sup>が公表されており，活用されたい．

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## 加齢による身体機能の変化と リハビリテーション医学

[Changes in Physical Function Due to Aging and Rehabilitation  
Medicine]

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Key words : 老化／サルコペニア／フレイル／ロコモティブシンドローム／ポストポリオ症候群

### はじめに

わが国の高齢化の進行は著しく、65歳以上の人口の割合（高齢化率）は年々上昇し、2022年には29.0%に達している<sup>1)</sup>。2022年に厚生労働省から発表された平均寿命は、男性81.05歳、女性87.09歳であり、今後も増加する見込みである。死因は割合の多いものから、がん（24.6%）、心疾患（14.8%）、老衰（11.4%）、脳血管疾患（6.8%）、肺炎（4.7%）、誤嚥性肺炎（3.6%）であり<sup>2)</sup>、医療を必要とする高齢者は増え、これらの疾患の予防や治療を行うことはリハビリテーション医学の重要な課題である。

また、高齢化に伴い要介護者も年々増加しており、2021年度末で要介護・要支援の認定者数は690万人を超えている<sup>3)</sup>。2022年に厚生労働省が実施した国民健康基礎調査では、介護が必要となった原因で多いものから認知症（16.6%）、脳血管疾患（16.1%）、骨折・転倒（13.9%）であり、要支援者の原因に限れば、多いものから関節疾患

（19.3%）、高齢による衰弱（17.4%）、骨折・転倒（16.1%）となっている<sup>4)</sup>。平均寿命の延伸とともに健康上の問題で日常生活が制限されることなく生活できる期間である健康寿命を延伸することが健康づくりの課題となっている。健康寿命を延伸するためには要介護・要支援の状態を予防・改善することが必要であり、リハビリテーション医学の果たす役割は大きい。

リハビリテーション医学で対象となる疾患・障害・病態はさまざまであるが、その多くが加齢に関係している<sup>5)</sup>（図1）。特に近年注目されているサルコペニア、フレイル、ロコモティブシンドローム（ロコモ）は加齢に関係した病態であり、その対策が重要である。

また、高齢化や社会状況の変化とともに人々の生き方も変化している。人生100年時代といわれ、定年まで1つの職場で働く価値観は変化し、ライフステージの変遷や働き方改革なども相まって、多様な生き方、働き方が求められている。職場では高年齢労働者が増え、それに伴い高年齢労働者の労働災害防止が重要な課題となっている。

### 加齢による身体機能の変化

加齢は人が生まれてから発達し成熟し老化し死に至るまでの年を重ねる全過程を指すことが多く、その中で老化は成熟した後に衰える過程を指すこ

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DOI : 10.2490/jjrmc.61.512





図1 リハビリテーション医学の対象となる疾患、病態、障害（文献5より引用）

とがあるが、両者を区別することは難しく、同様の意味で使われることもある。ここでは、加齢と老化をいずれも身体機能が衰える過程とみなして述べさせていきたい。

加齢による身体機能の変化は、分子・細胞レベルから臓器レベル、個体レベルとすべての階層で起こっている。呼吸、循環、消化器、血液、内分泌、腎機能などの臓器の機能低下はそれぞれの内部疾患の原因となる。神経や骨関節の機能低下は運動器疾患や歩行能力低下の原因となる。また、視覚の機能低下として、老眼、白内障などがあり、聴覚の機能低下として老人性難聴がある。視覚や聴覚の機能低下は転倒と関連があり<sup>6)</sup>、リハビリテーション治療における転倒予防対策として十分

配慮する必要がある。また、難聴は認知症発症のリスク因子としても寄与率が非常に高く、その対策が重要である<sup>7,8)</sup>。

## 加齢に伴う筋力・体力の変化

一般的に筋力は、20～30歳代をピークとして以後加齢とともに減少し、70～80歳代ではピーク時より20～40%低下する<sup>9)</sup>。体力テストの結果は、筋力や筋持久力の指標である上体起こし、柔軟性の指標である長座体前屈、敏捷性の指標である反復横跳び、全身持久力の指標である20mシャトルラン、最大酸素摂取量はいずれも20歳の手前にピークがあり、以後加齢とともに低下する<sup>10-12)</sup>。また、歩行速度や歩幅も加齢によって低下する<sup>13)</sup>。

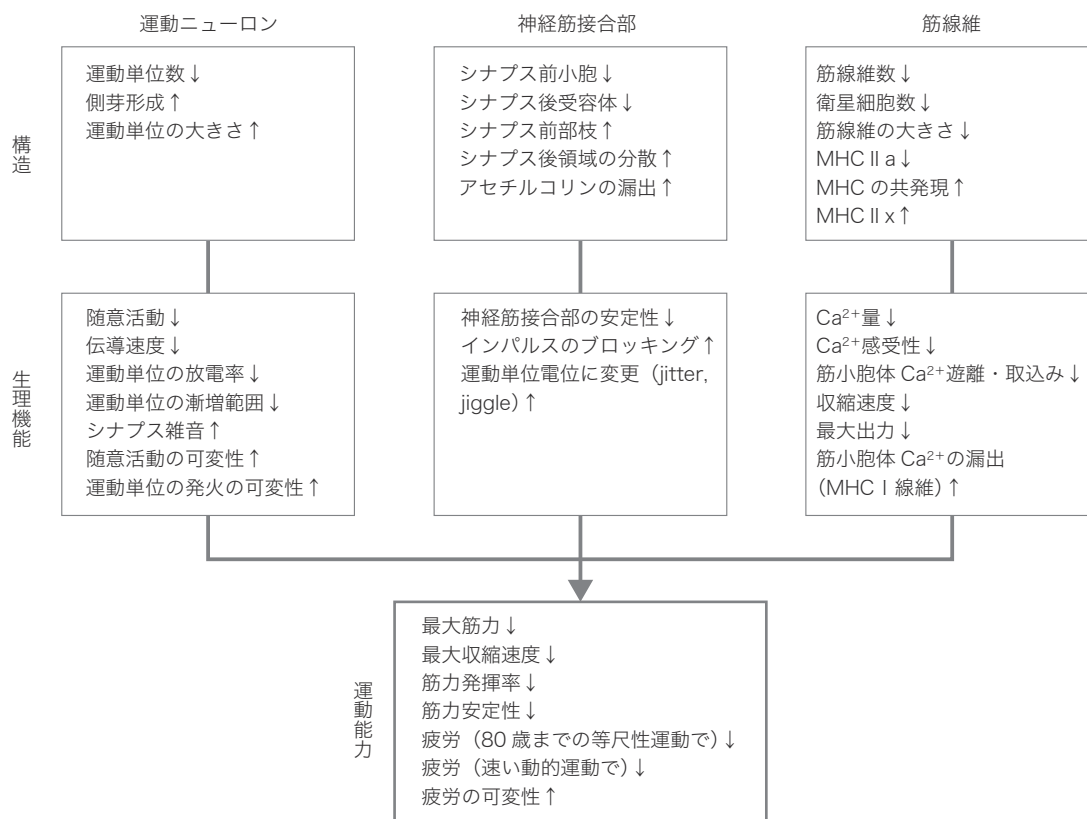


図2 加齢による神経筋システムの変化 (文献15より改変引用, 和訳)

↓は減少, ↑は増加を表す. MHC: myosin heavy chain

加齢とともに体力は低下するが、最近の高齢者では筋力、筋持久力、柔軟性、バランス能力、歩行能力など全般的に体力が向上していることも明らかになっている<sup>10)</sup>。

## 加齢に伴う筋肉の変化

骨格筋の筋線維にはミトコンドリアを多く含む type 1 線維とミトコンドリアが少なく解糖系酵素を多く含む type 2 線維の2種類があり、type 2 線維はさらに type 2A と type 2B に分けられる。type 1 線維が slow-twitch oxidative (SO) 型、type 2A 線維が fast-twitch oxidative glycolytic (FOG) 型、type 2B 線維が fast-twitch glycolytic (FG) 型に対応している。加齢に伴う筋肉量減少では、type 2 線維、特に速筋の特徴が強い type 2B

線維が選択的に萎縮し、廃用に伴う筋萎縮では抗重力筋に多い type 1 線維が優位に萎縮する<sup>14)</sup>。

加齢に伴う筋力低下の原因は筋肉量の減少だけでなく、運動ニューロン、神経筋接合部、筋線維を含む神経筋システム全体の変化が影響している<sup>15)</sup> (図2)。運動ニューロンでは運動単位数が減少し、伝導速度の低下や運動単位の放電率の低下が起こる。神経筋接合部では、シナプス前小胞やシナプス後受容体が減少し、アセチルコリンの漏出が増えて、機能が不安定となる。筋線維では、筋線維の大きさの減少だけでなく、筋線維数の減少や筋線維の再生に働く衛星細胞の減少が起こる<sup>15)</sup>。これらの神経筋システム全体の変化の結果として、筋収縮速度の低下や筋出力の低下が起こり、速い動的運動での疲労が起こりやすくなる。

表1 分子・細胞レベルの老化の原因 (文献16より作成, 和訳)

- ・ゲノム不安定性
- ・テロメア短縮
- ・エピジェネティックな変化
- ・タンパク質恒常性の喪失
- ・マクロオートファジーの無効化
- ・細胞老化
- ・ミトコンドリアの機能不全
- ・栄養感知の制御不全
- ・腸内細菌叢の異常
- ・慢性炎症
- ・細胞間コミュニケーションの変化
- ・幹細胞の枯渇

## 老化の原因

分子・細胞レベルの老化の原因として、12個の原因が挙げられている<sup>16)</sup> (表1)。すなわち、ゲノム不安定性、テロメア短縮、エピジェネティックな変化、タンパク質恒常性の喪失、マクロオートファジーの無効化、細胞老化、ミトコンドリアの機能不全、栄養感知の制御不全、腸内細菌叢の異常、慢性炎症、細胞間コミュニケーションの変化、幹細胞の枯渇である。細胞老化では、老化した細胞から炎症性サイトカインや細胞外マトリックス分解酵素などのさまざまな生理活性物質の分泌が亢進している現象である細胞老化関連分泌現象 (senescence-associated secretory phenotype : SASP) が関係している<sup>17)</sup>。分子・細胞レベルの老化のメカニズムを解明することや抗加齢医学との連携もリハビリテーション医学の大きな課題と思われる。

## サルコペニア、フレイル、ロコモティブシンドローム

加齢に伴う筋肉量減少であるサルコペニア、心身の虚弱を表すフレイル、運動器の障害のために移動機能の低下をきたした状態であるロコモは、加齢に伴う身体機能低下に関連した病態であり、リハビリテーション医学で重要な課題である。こ

れらの病態はさまざまな疾患で入院による治療の予後にも影響を与えることが知られている。

サルコペニアは加齢に伴う筋肉量減少であり、1989年にRosenbergが提唱した用語である<sup>18)</sup>。本来の意味である加齢が原因の筋肉量減少を一次性サルコペニア、低栄養、低活動、疾病が原因の筋肉量減少を二次性サルコペニアと分類される。原因やメカニズムは異なるが両者を区別することは難しく、二次性サルコペニアも含めて対策が行われる。サルコペニアの診断としては、Asian Working Group for Sarcopenia (AWGS) の2019年の診断基準が広く用いられている<sup>19)</sup>。ここでは筋肉量の低下に加えて、筋力の低下あるいは身体機能の低下があればサルコペニアと診断し、筋肉量の低下、筋力の低下、身体機能の低下のすべてを満たせば重度のサルコペニアと診断する。筋肉量の低下の診断には、下腿周囲径がスクリーニングとして用いられ、機器による測定が可能な施設においては、dual-energy X-ray absorptiometry (DXA) 法やバイオインピーダンス (BIA) 法を用いて四肢の除脂肪体重または骨格筋量を測定し、骨格筋量低下の有無を判定する。筋力としては握力が用いられ、男性28 kg未満、女性18 kg未満を筋力低下とみなす。身体機能の評価として、6 m歩行速度、5回椅子立ち上がりテスト、Short Physical Performance Battery (SPPB) のいずれかを用い、歩行速度は1 m/秒未満を身体機能低下とみなす。5回椅子立ち上がりテストは、腕を組んだ状態で椅子から5回立ち上がるのにかかった時間を測定し、12秒以上を身体機能低下と判定する。SPPBはバランステスト、立ち上がりテスト、歩行テストの3項目からなる合計12点の評価方法であり、9点以下を身体機能低下とみなす。

フレイルは英語の frailty の日本語訳として、2014年に日本老年医学会が提唱した用語である<sup>20)</sup>。身体的フレイル、精神心理的フレイル、社



会的フレイルに分けられ、筋力の低下により転倒しやすくなるような身体的問題のみならず、認知機能障害やうつなどの精神・心理的問題、独居や経済的困窮などの社会的問題を含む状態である<sup>20)</sup>。

ロコモは、2007年に日本整形外科学会が提唱した概念で、運動器の障害のために立ったり歩いたりするための身体能力（移動機能）が低下した状態である。原因となる運動器疾患には変形性関節症、変形性脊椎症、骨粗鬆症、骨折、関節リウマチなどが含まれる。ロコモの評価法としては、座った状態から片脚あるいは両脚で立ち上がることができるかを調べる立ち上がりテスト、2ステップの長さ（最大2歩幅）を測定する2ステップテスト、質問紙票であるロコモ25がある。3つのテストの結果をもとにロコモであるか否かを判定し、また、ロコモの段階を、移動機能の低下が始まっている状態であるロコモ度1、移動機能の低下が進行している状態であるロコモ度2、移動機能の低下が進行し社会参加に支障をきたしている状態であるロコモ度3のいずれの段階に該当するか判定し、ロコモ度3は身体的フレイルとみなされる<sup>21)</sup>。

サルコペニア、フレイル、ロコモの予防としては、タンパク質の摂取を含む栄養管理と筋力強化訓練を中心とした運動が重要である。ロコモに対する運動としては、ロコモーショントレーニング（ロコトレ）としてバランス能力をつける片脚立ちと下肢の筋力をつけるスクワットが推奨されている<sup>22)</sup>。

## ポストポリオ症候群 (post-polio syndrome : PPS)

ポリオはポリオウイルスの感染によって起こる感染症であり、わが国では1950年代に大流行して、その後ワクチン接種の効果によって新規患者がいなくなった。ポリオ罹患者が安定した状態が数十年続いた後に新たに筋力低下や筋萎縮、疲労感などを生じるポストポリオ症候群（post-polio syn-

drome : PPS）が問題となり、リハビリテーション医学でも重要な疾患である。

PPSで起こる筋力低下は、脱神経が代償的な神経再支配よりも超えて起こることによって考えられている。加齢もPPSの原因の1つであり、その他には過用や免疫学的因子、慢性炎症などが関与していることが報告されている<sup>23)</sup>。加齢によって運動単位数は減少するが、ポリオ罹患者では健常者よりも運動単位数は減少しており、運動単位数が麻痺の重症度と関係していることがわかっている<sup>24)</sup>。また、ポリオ罹患者では潜時や振幅、波形が同一な反復F波がみられることが特徴的であり、F波の測定や針筋電図による活動性脱神経電位の確認はPPSの診断に有用である<sup>25)</sup>。PPSのマネジメントとしては、不活動や過用を避ける生活指導、軽度～中等度の筋力強化訓練、適切な補装具の使用などが勧められる<sup>23, 26)</sup>。

産業医科大学では2001年から年に1回ポリオ検診を実施し、ポリオ罹患者の身体機能の変化を経時的に調査している。参加者の平均年齢は初回の2001年には52.8歳であったが、2023年には71.5歳と高齢化が進んでおり、PPSだけでなく腰痛や転倒、骨折など高齢化に伴う課題が増えている。ポリオ罹患者の筋力の変化は経年的に低下しているが、等運動性筋力測定機器で測定した筋力は、5年経過すると有意に低下している<sup>27, 28)</sup>（図3）。また、1年間あたりの筋力の低下率は膝伸展筋力のほうが膝屈曲筋力よりも有意に低下している<sup>27, 28)</sup>。

## 高齢労働者への対応

60歳以上の雇用者数は過去10年で1.5倍に増加し、2022年には労働災害の休業4日以上死傷者の28.7%が60歳以上である<sup>29)</sup>。高齢労働者では、視力、聴力、バランス能力、筋力などが低下していることが問題となり、高齢労働者の安全と

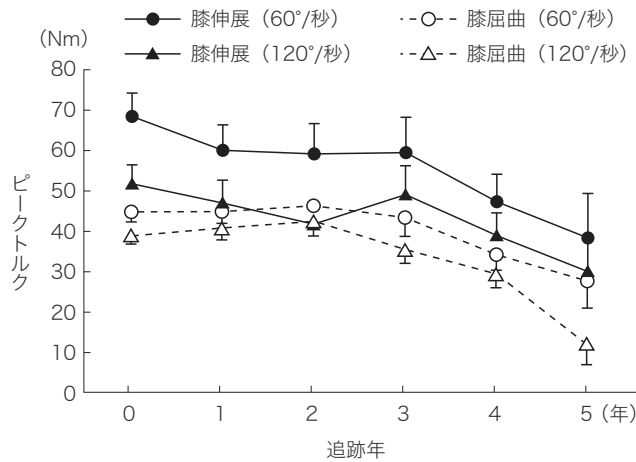


図3 ポリオ罹患者における加齢による筋力の変化（文献27より引用）

等運動性筋力測定機器（Biodex）での膝伸展および膝屈曲の筋力（ピークトルク）を60°/秒、120°/秒の角速度で測定している。

健康の確保は労働衛生の現場で重要な課題となっている。2020年3月に厚生労働省は、高年齢労働者の安全と健康確保のためのガイドライン（エイジフレンドリーガイドライン）を策定した<sup>30)</sup>。この中で高年齢労働者に配慮した職場環境の改善例として、段差をなくすことや照明を明るくするなどの転倒予防のための環境改善や、腰痛予防のために介護現場でリフターやトランスファーボードを使用することなどが推奨されている。また、ガイドラインでは、高年齢労働者に対する体力チェックの実施や高年齢労働者の身体機能の維持向上のためにフレイルやロコモの予防に取り組むことも推奨されている。このように転倒予防や腰痛予防、フレイルやロコモ対策など、高年齢労働者への対応には、リハビリテーション医学の知識や経験を生かすことができる。

## おわりに

加齢による身体機能の変化は、分子・細胞レベルから起こっており、そのメカニズムの解明や筋力低下や運動機能低下に対する基礎研究は重要で

ある。サルコペニア、フレイル、ロコモを適切に診断し改善することはリハビリテーション医学の重要な課題であり、高年齢労働者への対策の中でもリハビリテーション医学が果たす役割は大きいと考える。

本論文発表内容に関して申告すべきCOIはなし。

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## ポリオのカーボン製下肢装具の適合をはかる

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蜂須賀明子<sup>1)</sup> <sup>2)</sup>，松嶋康之<sup>2)</sup>，尾崎文<sup>2)</sup>  
杉本香苗<sup>2)</sup>，荒井光男<sup>3)</sup>，佐伯寛<sup>2)</sup>

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# 第40回日本義肢装具学会学術大会 C O I 開示

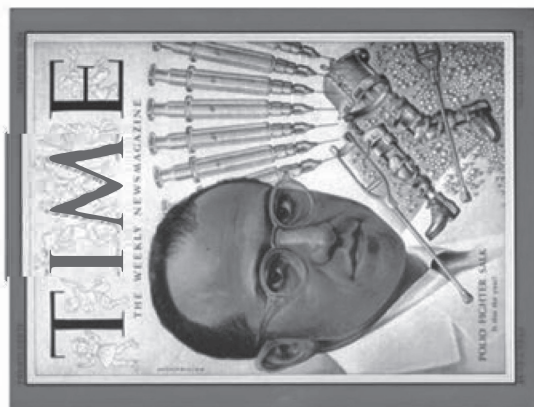
筆頭発表者名：蜂須賀 明子

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。

# ポリオの発生状況

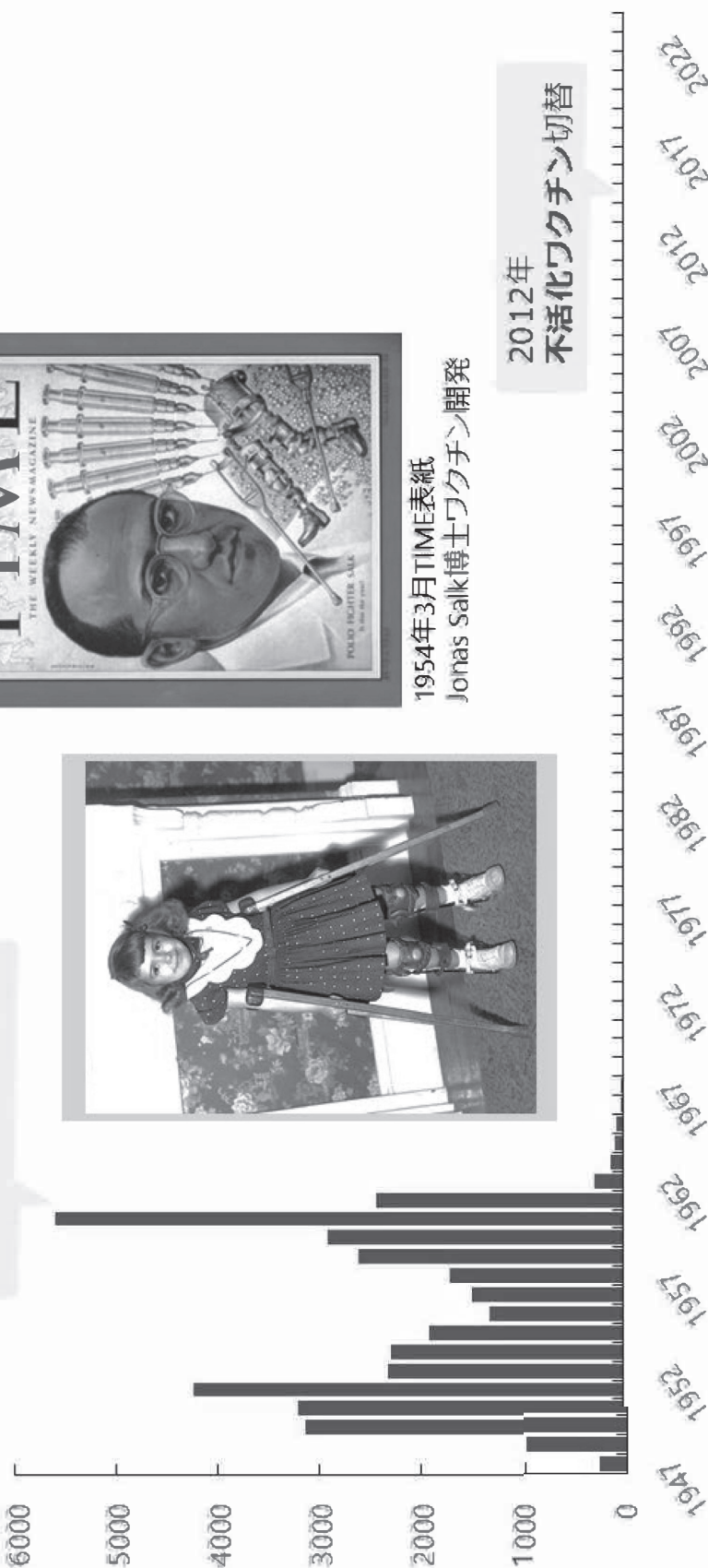
患者数 (人)

1961年  
経口生ワクチン導入



1954年3月TIME表紙  
Jonas Salk博士ワクチン開発

2012年  
不活化ワクチン切替



# ポリオの臨床像

ポリオウイルス罹患  
脊髄前角細胞障害

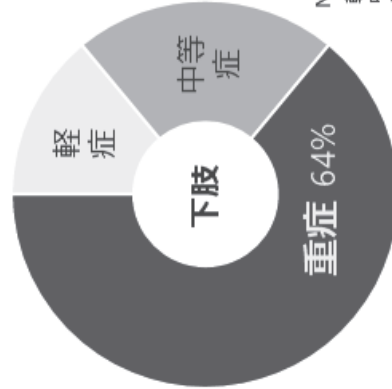
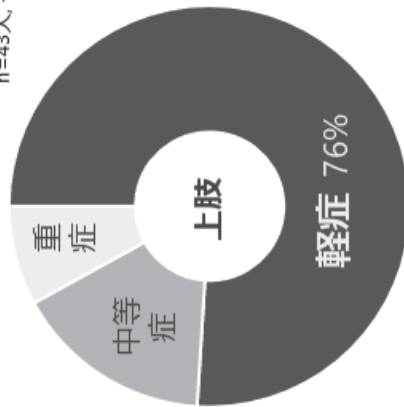
麻痺の回復・固定

0歳  
1歳  
学童期  
学生期  
社会人  
定年



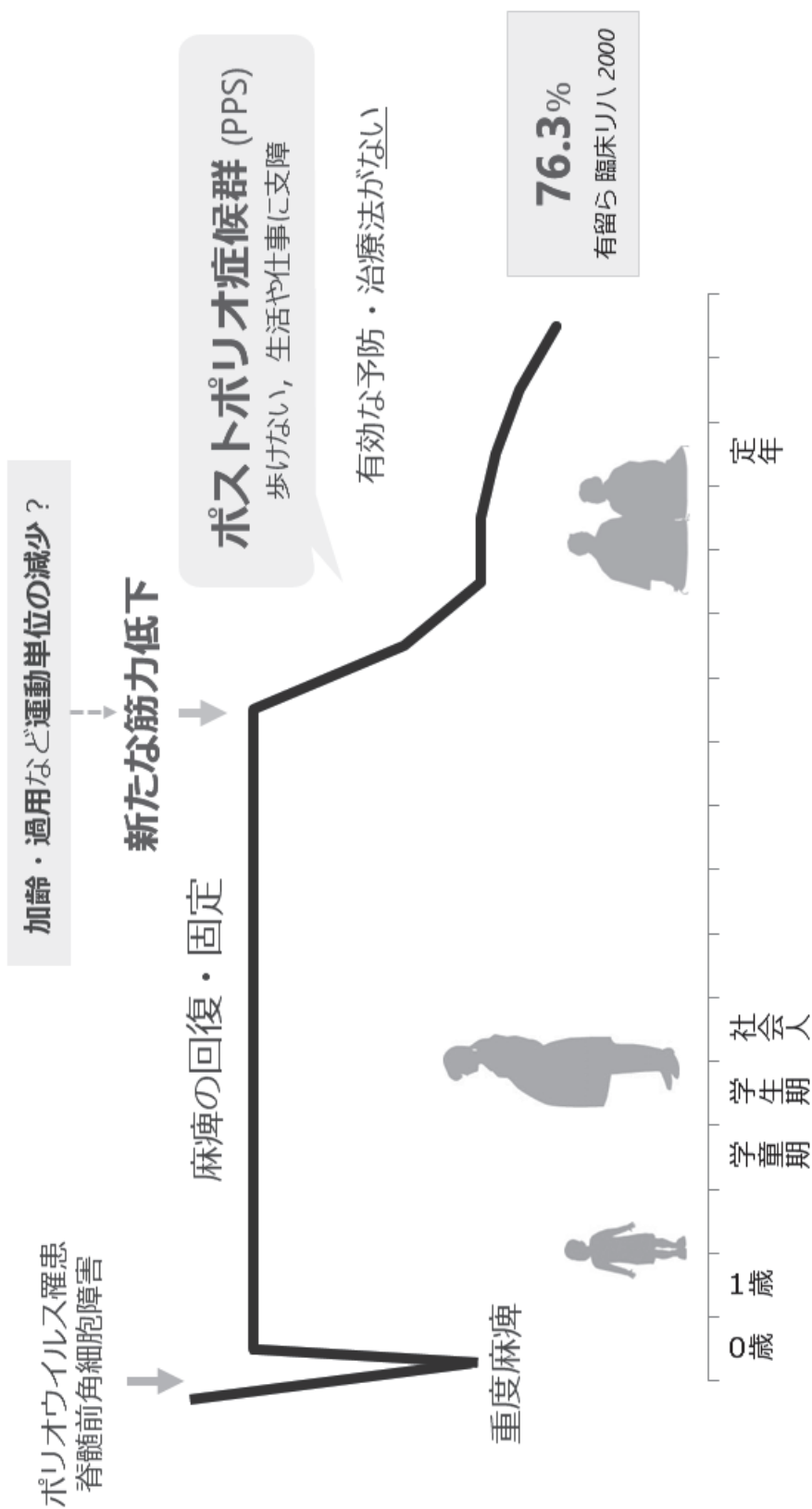
## ポリオの臨床重症度

n=43人、各86肢



NRH肢体別重症度分類  
軽症：NRH I, NRH II  
中等症：NRH III  
重症：NRH IV, NRH V

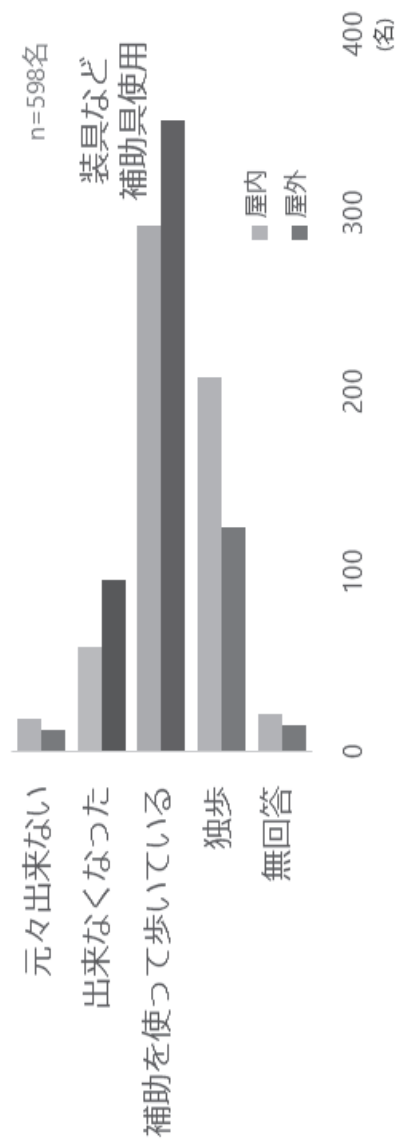
# ポストポリオ症候群



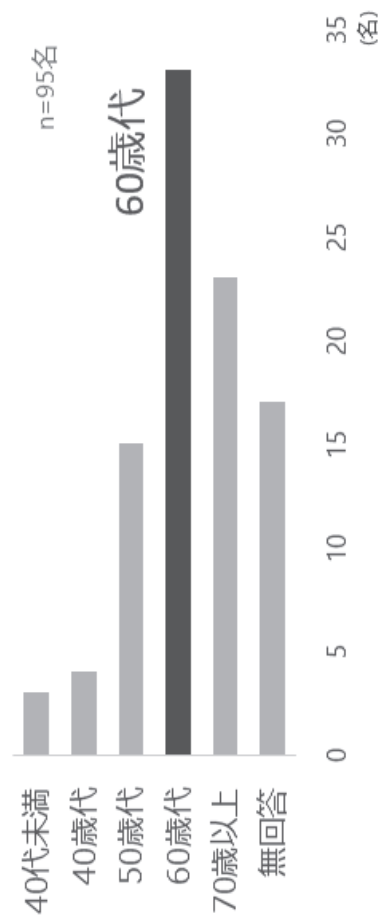
15年以上の安定期の後, 新たな筋力低下が出現する病態

# ポリオ罹患者の歩行状況

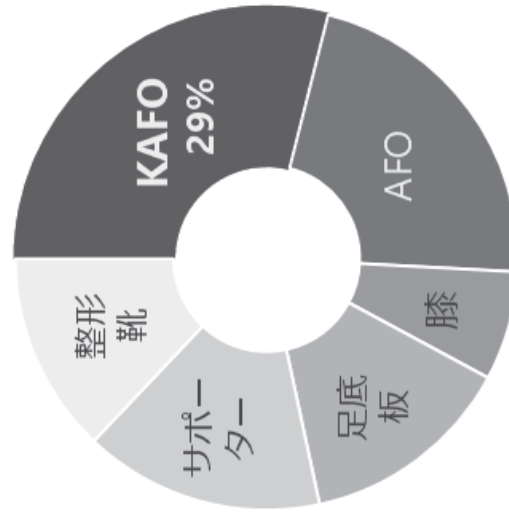
歩くことの可否（屋内・屋外）



歩くことが出来なくなった時期（屋外）



歩行のために使用している装具

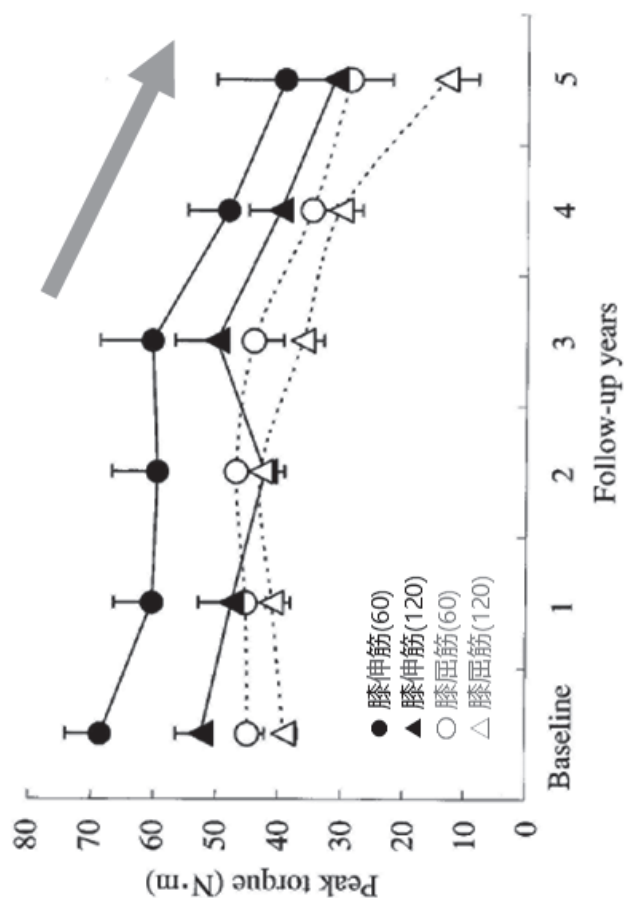


全国ポリオ会連絡会 No.67 2023  
アンケート結果より一部改変

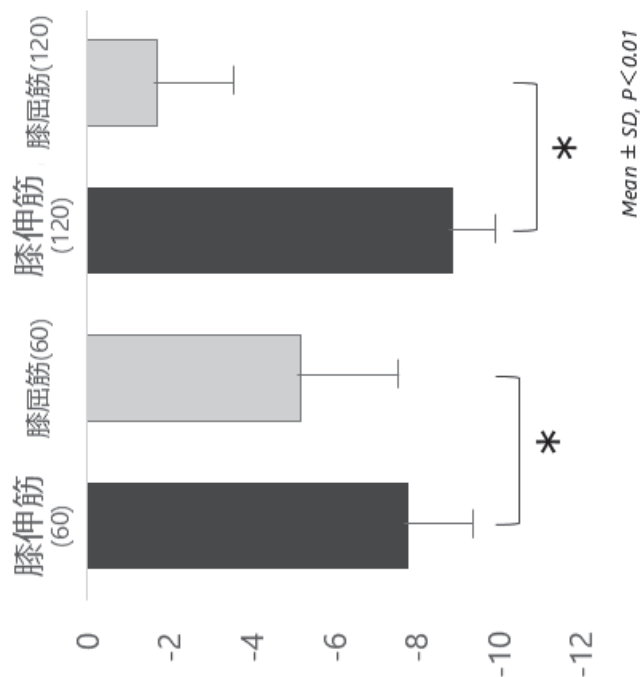
# ポリオ罹患者の下肢筋力

## 膝屈伸筋力 -5年間の変化-

Biodex n=63名 (76肢) , 平均年齢 54.5歳



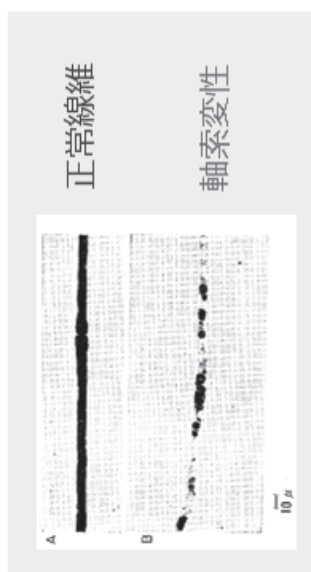
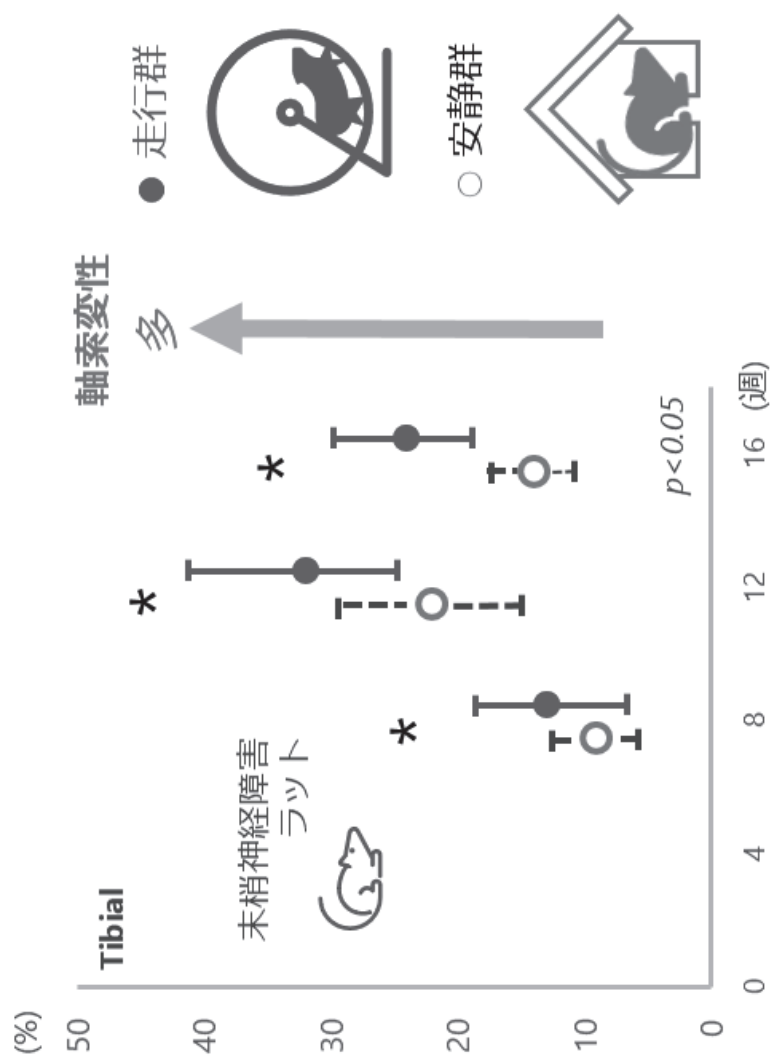
## 筋力ピークトルク値の年間変化率



経時的な筋力低下あり 膝伸筋 > 膝屈筋群

# Overwork weakness -運動と筋力-

## 軸索変性線維の出現率



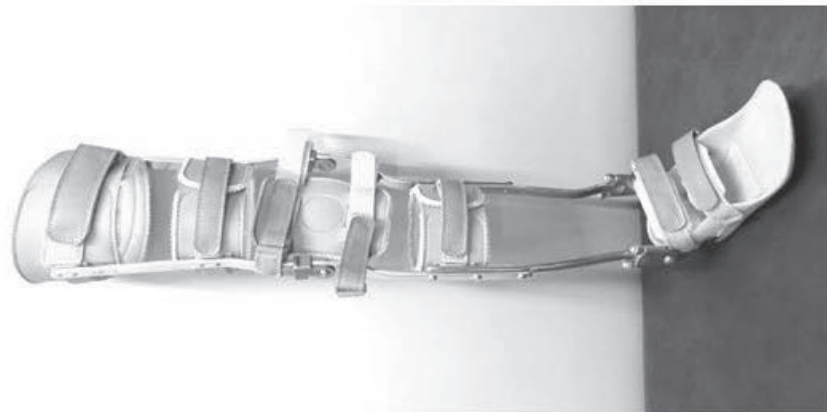
- 末梢神経障害において、  
**過度の身体的活動に起因して筋力低下を呈する病態**
- “過用性筋力低下”とも言う。

蜂須賀, リハ医学 1983

## 従来型長下肢装具



Polioplace  
<https://www.polioplace.org/history/artifacts/reliant-poster-child>



両側支柱付き長下肢装具

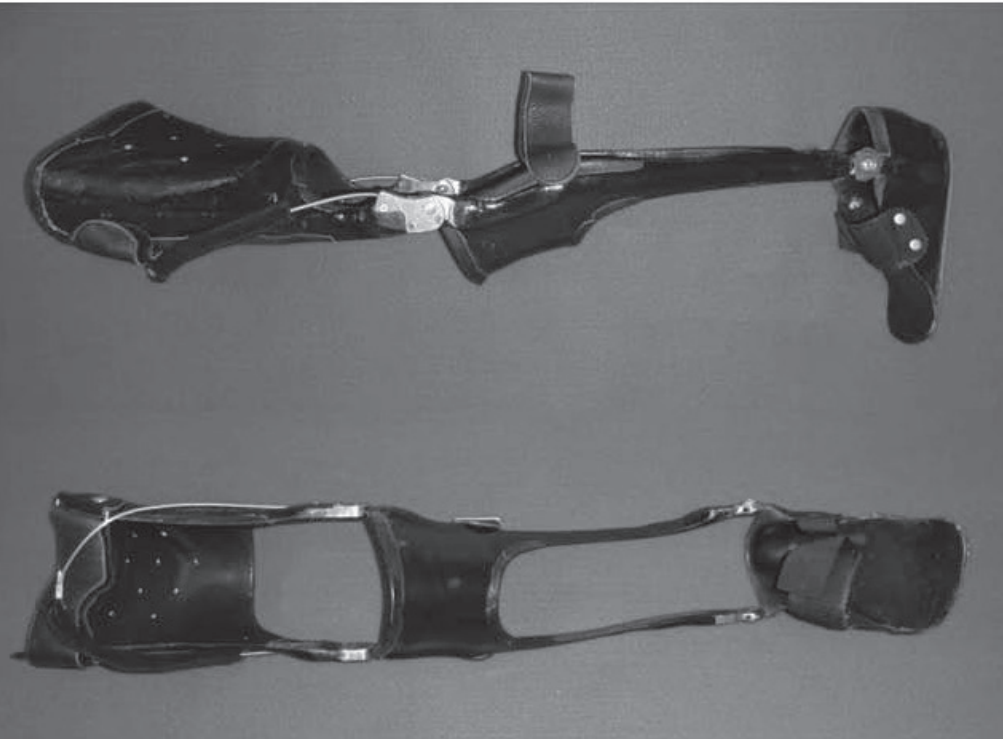
### 【従来型KAFO】

- 重量が重い  
→ 過負荷のリスク
- 外観が悪い
- 変形を伴う体に合わない

\* 従来型長下肢装具（従来型KAFO）



# カーボン製長下肢装具



## 【カーボン製KAFO】

- ・ 軽量
- ・ 適合・外観が良い
- ・ 歩行効率の向上

\*カーボン製長下肢装具（カーボン製KAFO）



カーボン繊維（足部作製過程）

2001年 産業医科大学病院リハビリテーション科外来  
ポリオ患者に対するカーボン製KAFOの作製開始

## カーボン製KAFOは軽量

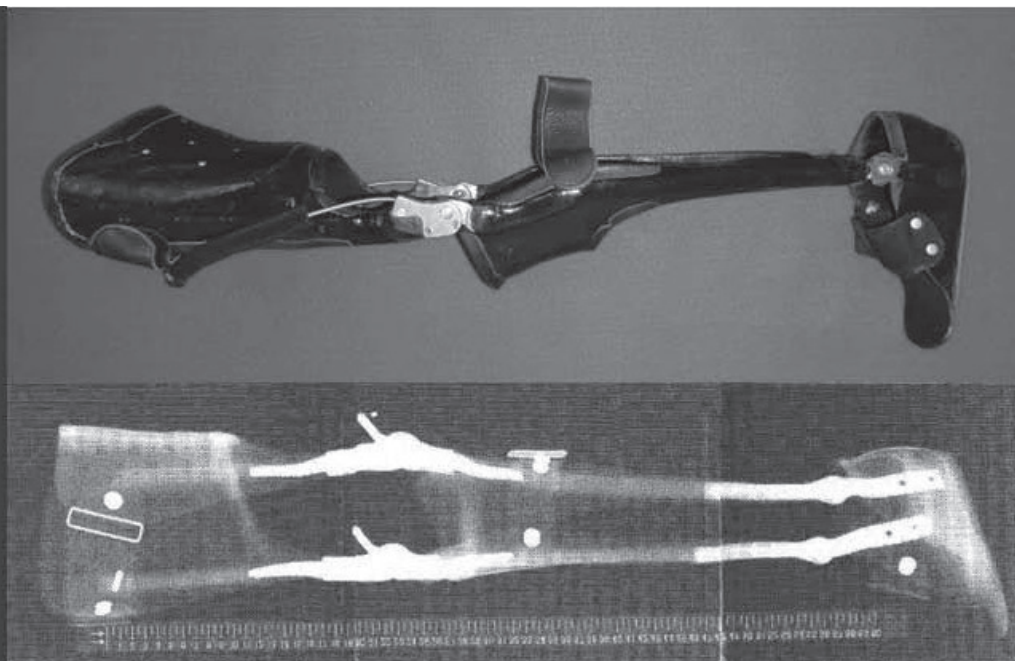
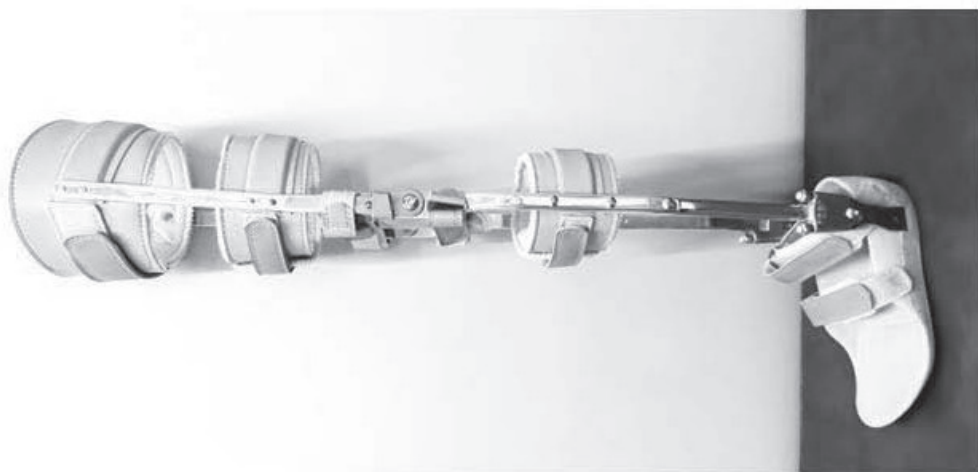
- 金属の一部 → カーボンに置き換え
- カーボン繊維強化樹脂，剛性高い  
→ 単独樹脂より薄く仕上げ可
- チタン合金膝継手

負荷軽減



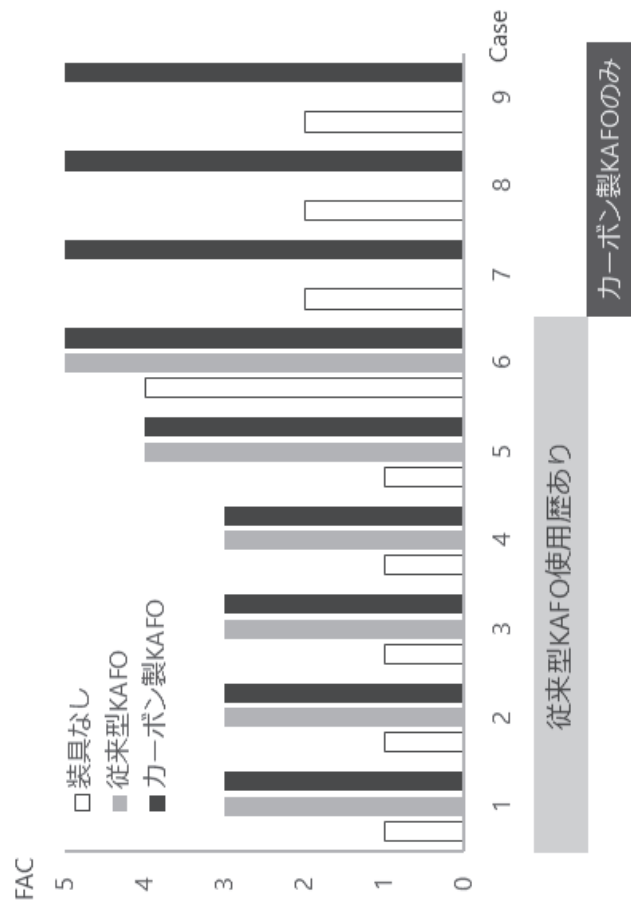
カーボン製KAFO  
約900g

従来型KAFO  
約1400g



# カーボン製KAFO 軽量・外観・歩行の満足度高い

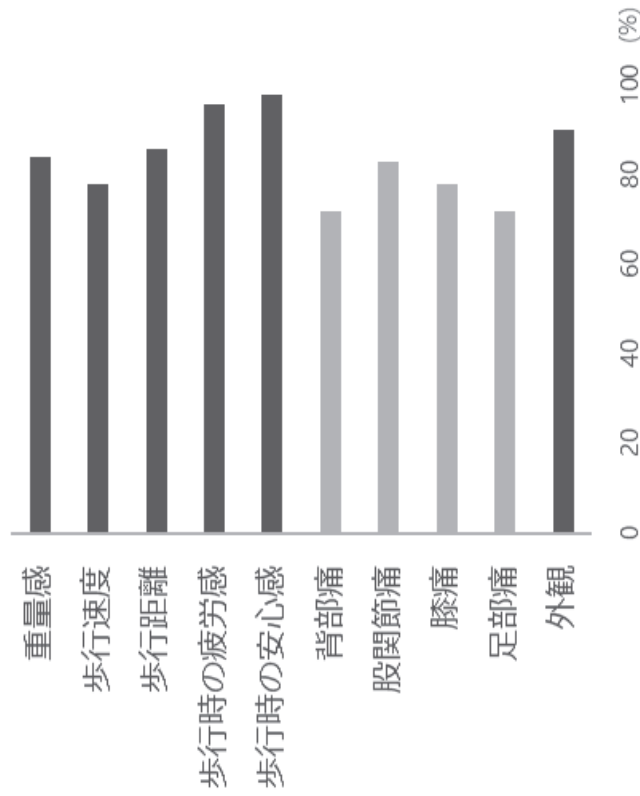
## Functional Ambulation Category



- ・カーボン製KAFOを作製したポリオ9名（11肢）

従来型KAFOとカーボン製KAFO FACは差なし

## 従来型KAFO使用歴（+）ポリオ罹患者の カーボン製KAFOの主観的評価



歩行関連、外観、軽量の満足度高い

Hachisuka K, et al. Prosthet Orthot Int. 2006

# カーボン製KAFOは歩行効率が良い

## 装具なし vs カーボン製KAFO

	装具なし	カーボン製 KAFO
歩行率 (歩/min)	77.0 ± 12.5	84.3 ± 13.2
歩幅 (cm)	39.7 ± 7.5	45.6 ± 7.0
歩行速度 (m/min)	31.0 ± 8.5	39.5 ± 9.8 *
酸素摂取量 (m/min/kg)	13.5 ± 4.7	11.4 ± 2.7 *
酸素コスト (ml/m/kg)	0.46 ± 0.14	0.30 ± 0.09 *
Physiological cost index	1.07 ± 0.47	0.72 ± 0.44 *

Paired t-test \* $p < 0.05$

- ・ 装具なし歩行が可能でカーボン製KAFOを作製した8名
- ・ 5 分間の快適歩行

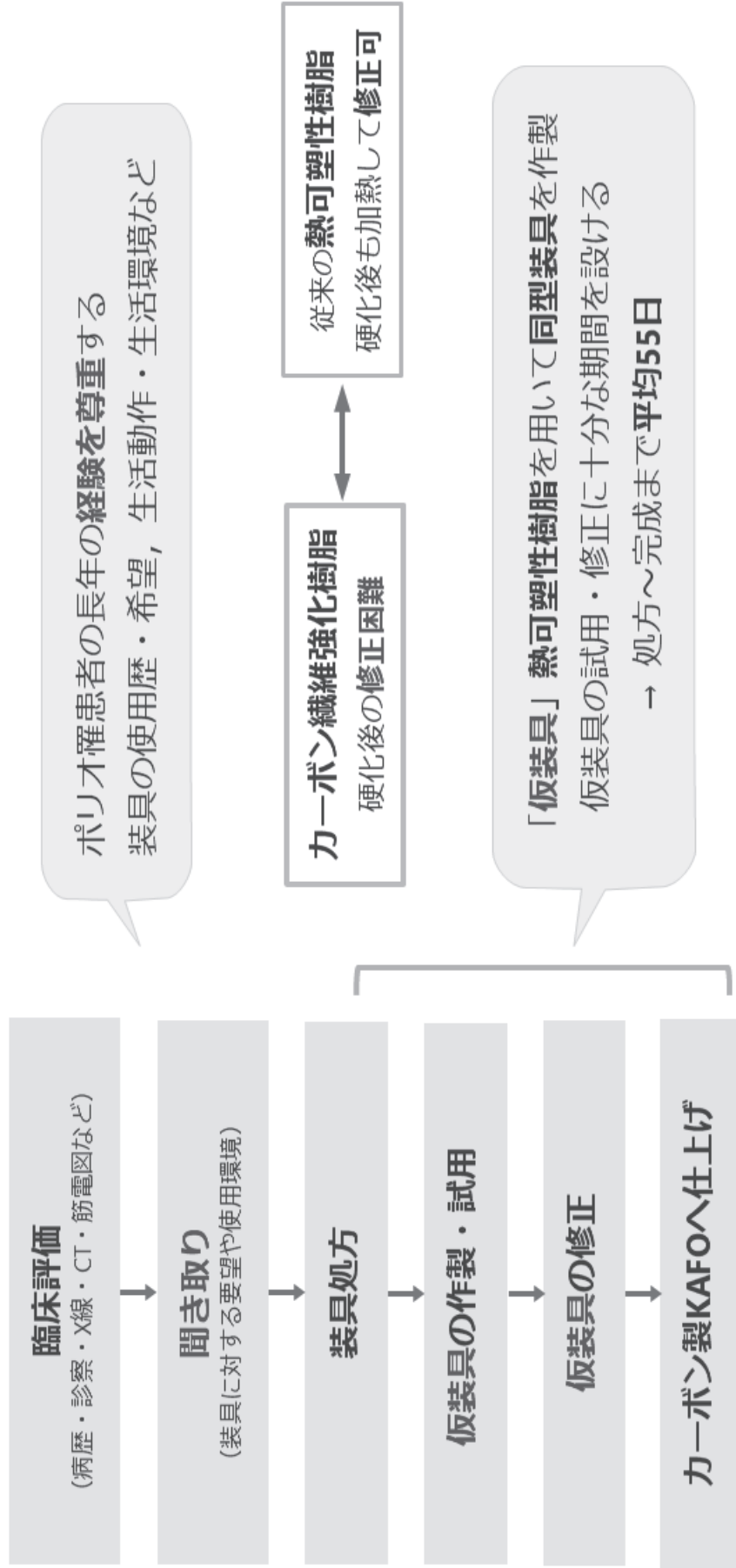
## 従来型KAFO vs カーボン製KAFO

	従来型 KAFO	カーボン製 KAFO
歩行率 (歩/min)	92.9 ± 6.3	92.0 ± 11.1
歩幅 (cm)	41.3 ± 7.0	45.7 ± 8.2
歩行速度 (m/min)	38.5 ± 7.0	42.6 ± 7.8 *
酸素摂取量 (m/min/kg)	14.0 ± 3.2	12.8 ± 2.4 *
酸素コスト (ml/m/kg)	0.37 ± 0.08	0.32 ± 0.09 *
Physiological cost index	0.95 ± 0.36	0.81 ± 0.43 *

Paired t-test \* $p < 0.05$

- ・ 従来型KAFO使用しておりカーボン製KAFOを作製した8名
- ・ 5 分間の快適歩行

# カーボン製KAFO 製作の流れ





## 麻痺・装具歴・新たな筋力低下

### 臨床評価

(病歴・診察・X線・CT・筋電図など)



### 聞き取り

(装具に対する要望や使用環境)



### 【病歴】

1歳頃にポリオに罹患，両下肢弛緩性麻痺の後遺症．小学校入学後は**両松葉杖**で歩行していた．10歳で左足関節固定術を受けて**左長下肢装具**を装着したが，12歳から**装具なし・両松葉杖**歩行であった．20歳頃には**左T字杖のみ**，長距離は**両T字杖**を使用．

61歳頃より**右下肢の膝折れ**が出現，66歳頃より右膝折れによる**転倒が増加**した．他院外来リハビリの診察でカーボン製KAFO作製を勧められ，1年間悩んだ末に当科紹介受診．

### 【社会的背景】

手帳：身体障害者手帳2級（肢体不自由，両下肢機能障害）

住居：自宅は2階建て，居室2階，階段は手すりなく這って昇降

トイレ洋式，布団生活

職業：**洋裁の自営業**

店舗（平屋）で就寝することも多く，**滞在時間が長い**



# 身体所見・画像・生理機能検査

## 臨床評価

(病歴・診察・X線・CT・筋電図など)



## 聞き取り

(装具に対する要望や使用環境)

## 【身体所見】

SMD 75cm/70cm, 脚長差 5cm

ROM: 膝関節 伸展 0/5 外反 0/20

足関節 背屈 0/-10 WKE 底屈 50/10

MMT: G.max 2/0 G.med 2/0 Ilio 3/0

Quad 3/0 TA 3/0 Gastro 3/0

## 【筋電図】

右Quad: 活動性所見(-), 高振幅および多相性MUP

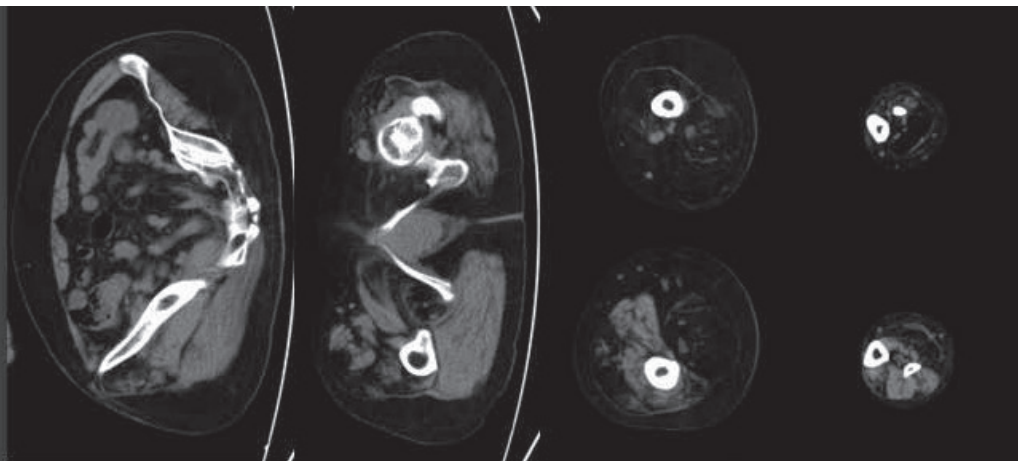
遅延動員, 干渉減少

左Quad: Electrical Silence



"病態がみえる"  
患者と共有

足底は豊富な情報源



# チームで聞く・診る

## 臨床評価

(病歴・診察・X線・CT・筋電図など)



## 聞き取り

(装具に対する要望や使用環境)



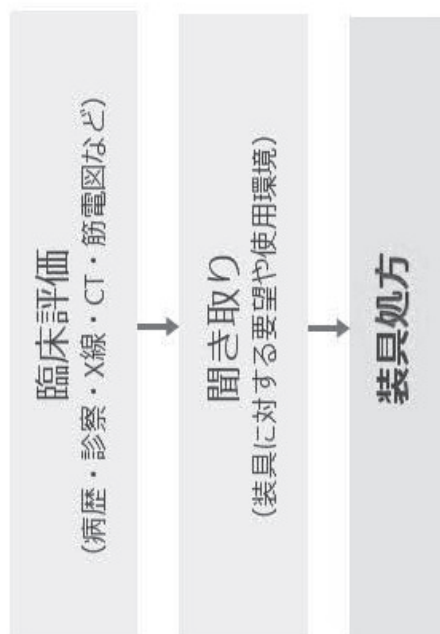
左下肢：反張膝・外反膝として歩行安定化

⚡ 装具外来  
お役立ちアイテム



仕事を続けたい！  
床で洋裁作業をしたり，  
膝立ちや起立してお客さんに合わせたり...

# カーボン製KAFOの処方

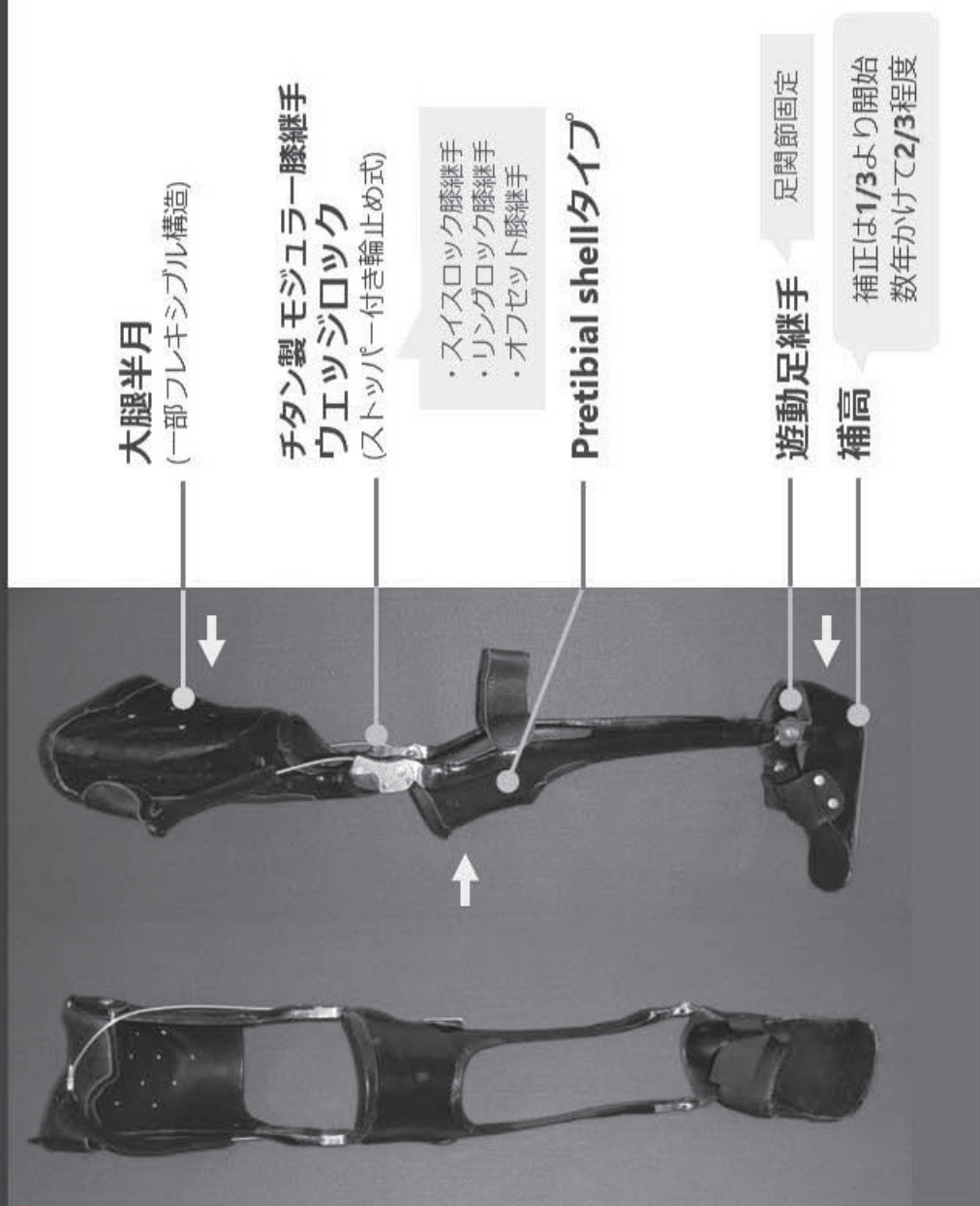


膝前面  
圧迫なし



柔らかく  
座面に馴染む

座位も  
快適



大腿半月

(一部フレキシブル構造)

チタン製モジュラー膝継手  
ウェッジロック

(ストッパー付き輪止め式)

- ・スイスロック膝継手
- ・リングロック膝継手
- ・オフセット膝継手

Pretibial shellタイプ

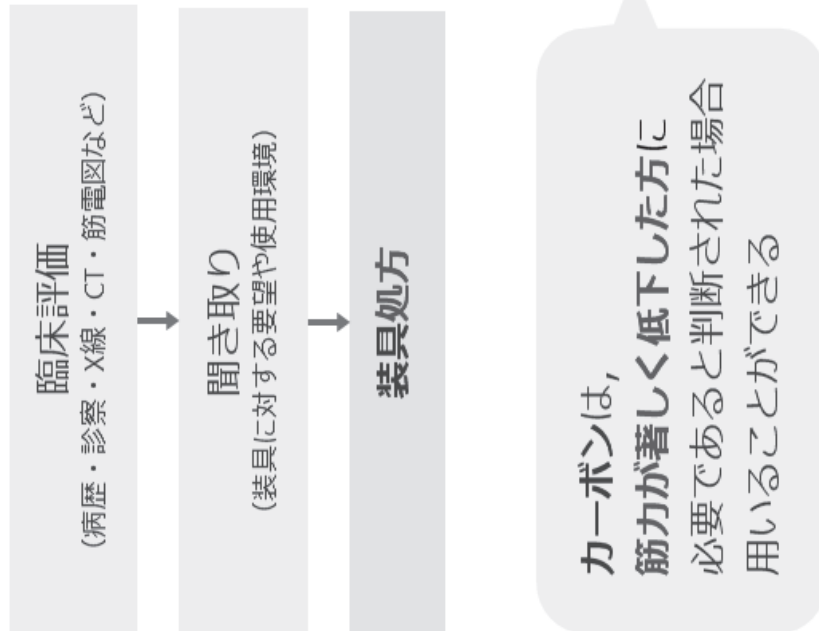
遊動足継手

足関節固定

補高

補正は1/3より開始  
数年かけて2/3程度

# カーボン製KAFO 装具意見書



## 義肢・装具意見書

氏 名	生年月日	T・S・H・R	年	月	日 ( 歳)
現 住 所					
障 害 名			障害等級		級
現 症 *おもに障がいの 原因となる原疾患 の病名と病歴、現 在の身体状況等及 び能力低下をきた す原因となる機能 障がい等について も具体的に記入し てください。	<p>小児麻痺後遺症による両下肢弛緩性麻痺 MMT: 大殿筋2/0 中殿筋 2/0 腸腰筋 3/0 大腿四頭筋 3/0 前脛骨筋 3/0 下腿三頭筋 3/0 起立歩行には左長下肢装具と両T字杖を要する。</p> <p><b>高度の筋力低下のため (PPS予防のため)</b> <b>軽量のカーボン製長下肢装具が必要。</b></p>				
補 装 具 の 名 称	<p>(注: タイプ名を記載してください。) 左カーボン製長下肢装具</p>				



# カーボン製KAFO 下肢装具処方箋

臨床評価  
(病歴・診察・X線・CT・筋電図など)



聞き取り  
(装具に対する要望や使用環境)



装具処方

カーボンは、  
筋力が著しく低下した方に  
必要であると判断された場合  
用いることができる

基本型式												
名称	股	長下股	膝	短下股	足底	股関節外転	両長下股	靴型				
採型	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10	B-1	B-2
採寸			○									
構造	両側支柱 片側支柱 硬性(F1, E2) S型支柱 硬ばね 軟性 その他 ( )											
カーボン製チェック用装具加算												
大腿部 足部 各1												
固定式 遊動式												
継	股	× ( ) × ( )										
手	膝 (片側)	固定式	遊動式 プラスチックス継平									
		× ( )	× ( 2 ) × ( )									
支	足 (片側)	固定式	遊動式 プラスチックス継平									
		× ( )	× ( 2 ) × ( )									
持	仙	モールド (支柱付き) その他 ( )										
	腸	× ( )	× ( )									
部	大	A 半月	B 皮革等	C モールド カーボン × ( ) 1. カフバンド 1. 熱硬化性樹脂 2. 大腿コルセット 2. 熱可塑性樹脂								
	腿	× ( )	× ( ) × ( )									
	下	A 半月	B 皮革等	C モールド カーボン × ( ) 1. カフバンド 1. 熱硬化性樹脂 2. 下腿コルセット 2. 熱可塑性樹脂								
	腿	× ( )	× ( ) × ( ) PTB式 ×1									
	足	A あふみ	B 足部	C 標準靴 カーボン × ( ) 1. 皮革等 (大・小) 1. 熱硬化性樹脂 2. モールド (熱硬化性樹脂) 2. 熱可塑性樹脂 3. モールド (熱可塑性樹脂) 3. モールド (熱可塑性樹脂)								
	部	× ( )	× ( ) × ( )									

カーボン製  
チエック用装具加算

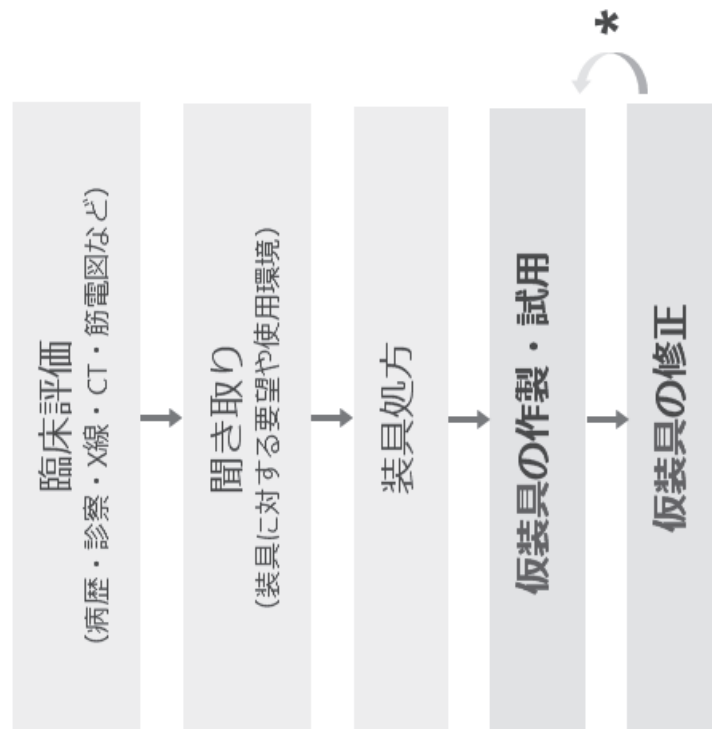
支持部：カーボン  
大腿・下腿・足部

見積金額

約 ¥ 400,000

福岡県 補装具申請様式一装具  
<https://www.pref.fukuoka.lg.jp/contents/hoso-gu.html>

# 「仮装具」 時間をかけて丁寧に調整



## 採型～完成まで スケジュール例

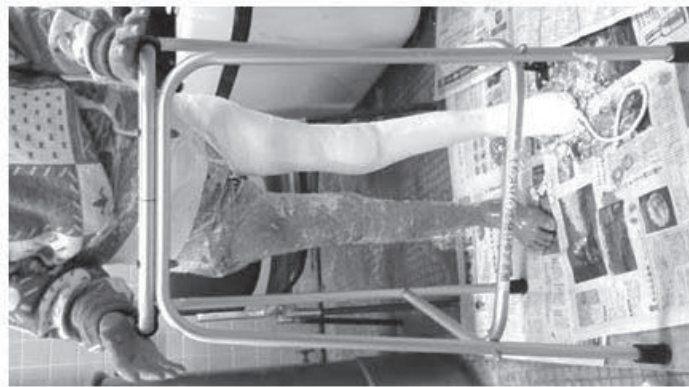
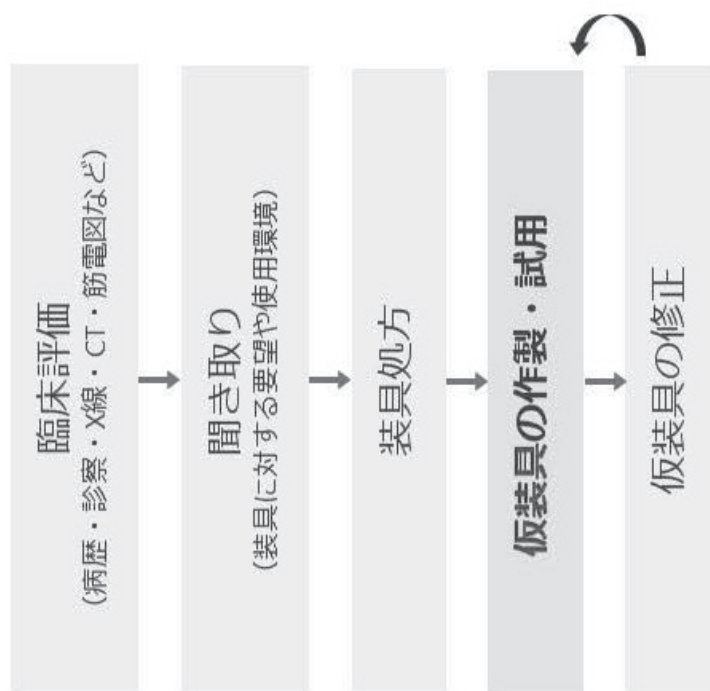
	月	火	水	木	金	土	日
1w		装具外来・採型					
2w							
3w		仮装具完成 *					
4w		装具外来 *					
5w		装具外来 *					
6w		装具外来 *					
7w		(装具外来 *)					
8w		装具外来・仕上げ *					
9w							
10w		装具外来 カーボン製装具完成					

**入院**  
仮装具試用・修正  
リハビリテーション訓練

**自宅**  
仮装具の試用



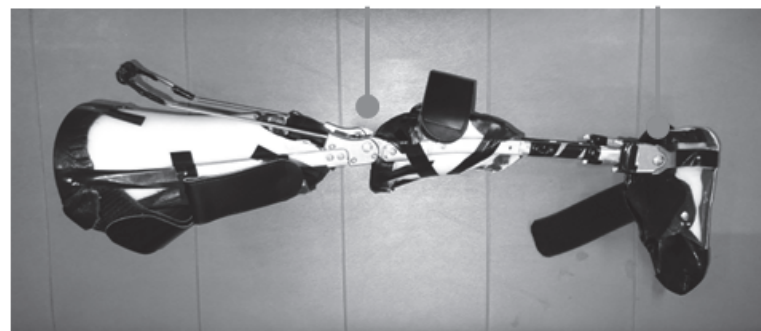
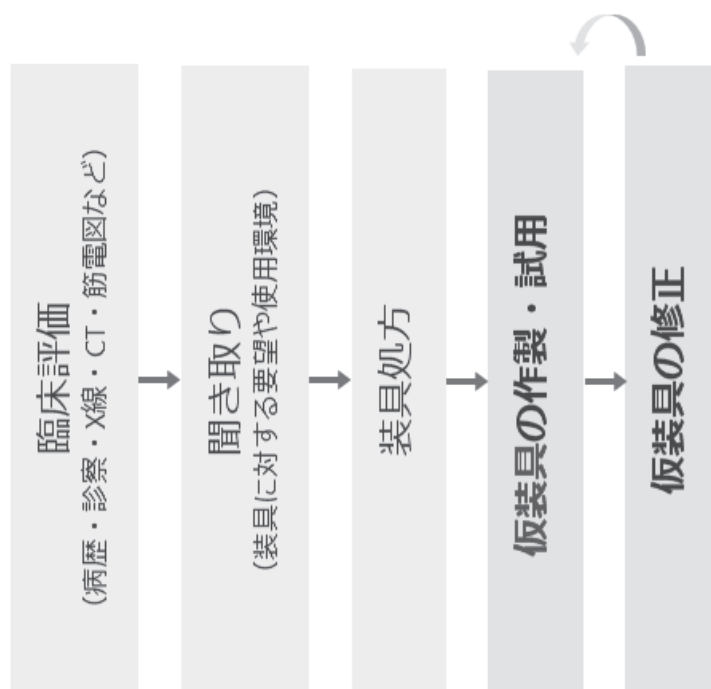
## 「仮装具」 採型は立位・荷重



今回は、  
脚長差5cm  
補高2cm

高度の反張膝・外反膝の矯正程度，補高など  
医師・義肢装具士・患者間で十分に検討

## 「仮装具」 試用・修正の繰り返し



チタン製 モジュラー膝継手  
ウェッジロック  
(ストッパー付き輪止め式)

カーボン装具・同型

ダブルクレンザック  
足継手

仮装具・調整用

- 疼痛
- 関節軸の位置
- 支柱のクリアランス

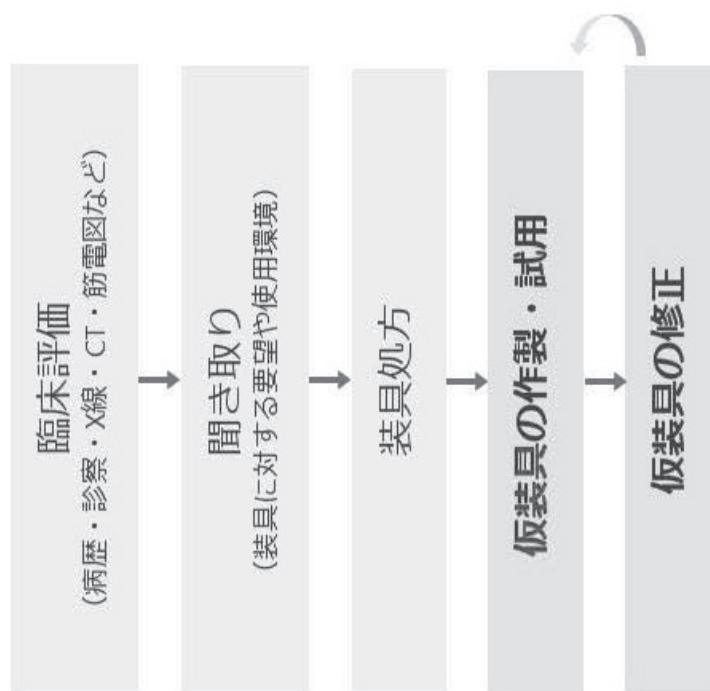
- 装着, 脱着
- 膝ロック, 解除

- 補高
- 靴の差高
- 足継手の可動域

- 歩行
- 希望する生活動作

熱可塑性樹脂を用いる  
同デザインの**仮装具**

## 仮装具・歩行

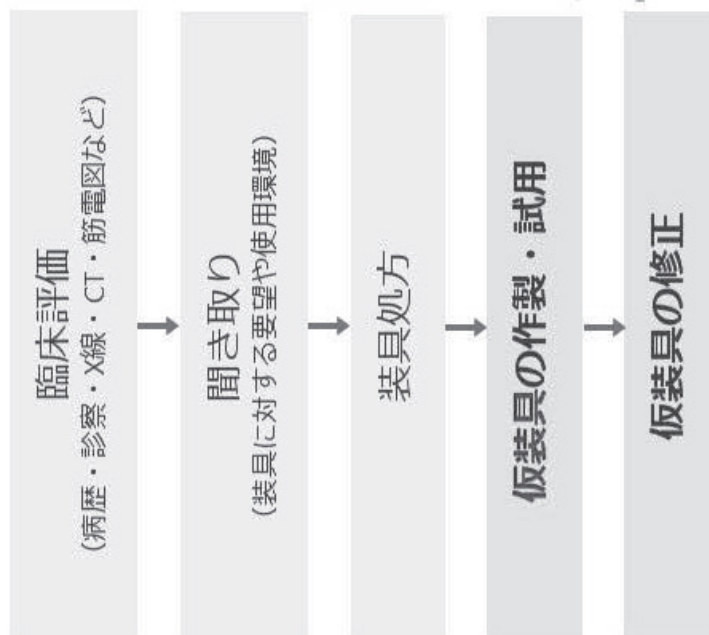


 装具外来  
お役立ちアイテム



- 補高
- 靴の差高
- 足継手の可動域

# 仮装具・希望する生活動作 膝立ち・立ち上がり



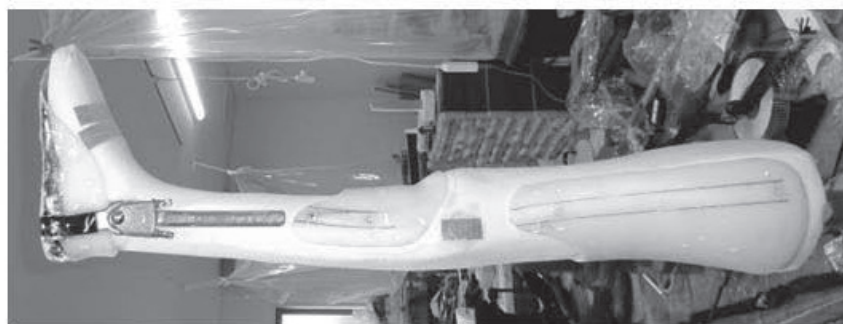
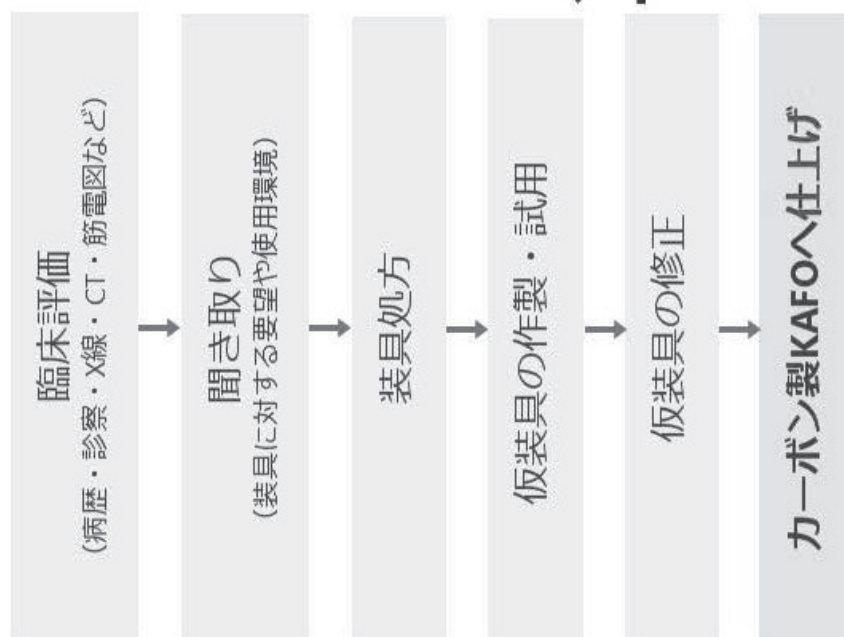
膝立ちが  
少し不安定💧

ここが  
痛い💧です





# 仮装具 → カーボン製KAFOへ仕上げ



仮装具 → 陽性モデル



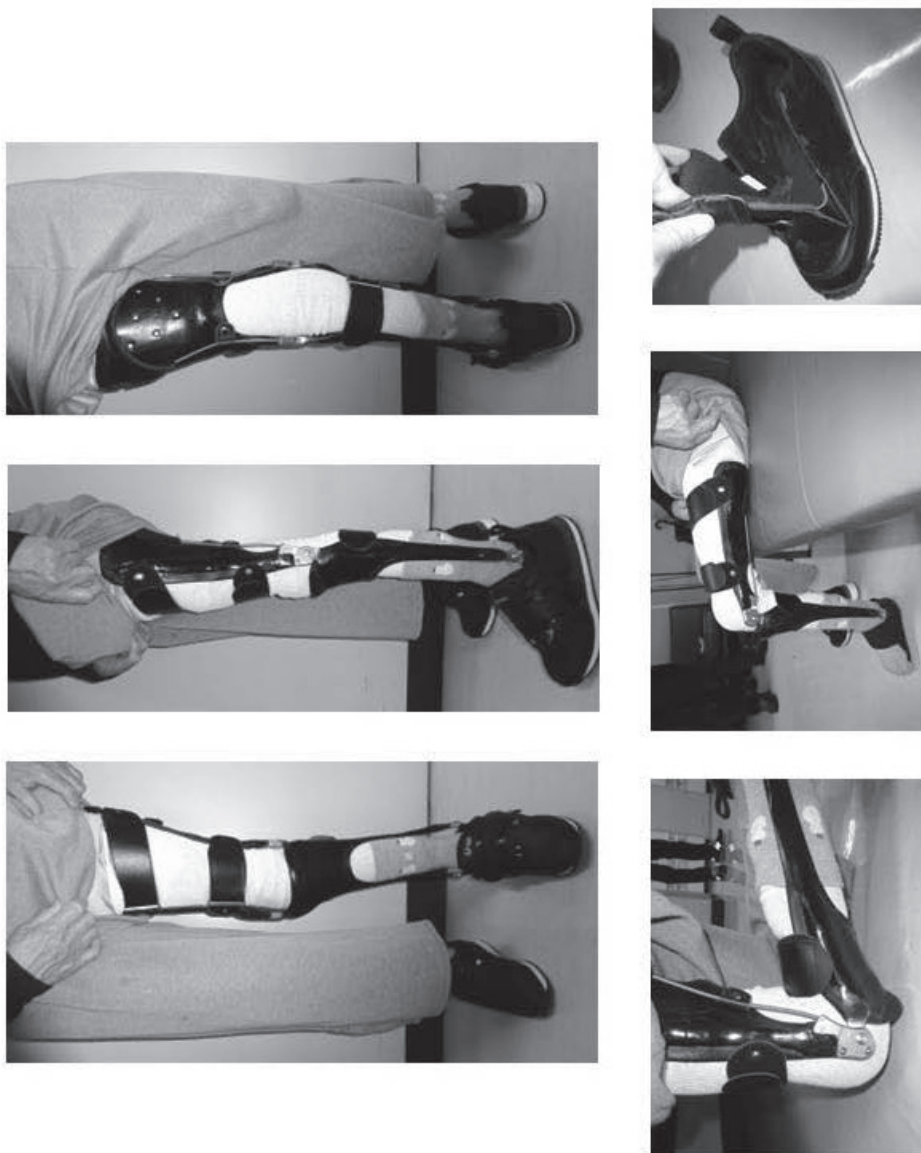
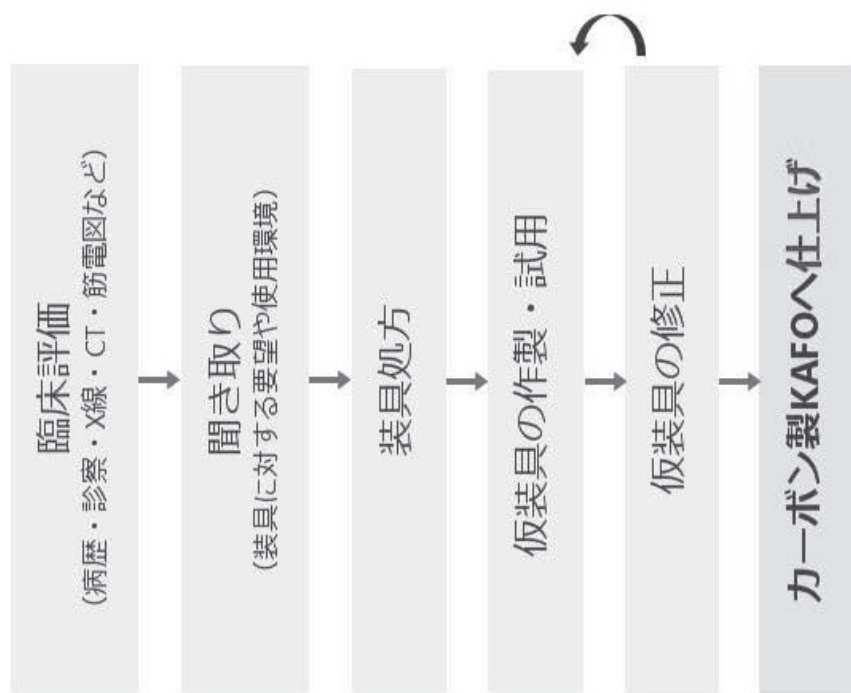
カーボン繊維  
継手・半月・足部



金属穴にカーボン繊維  
剥離防止，捻じれに強い

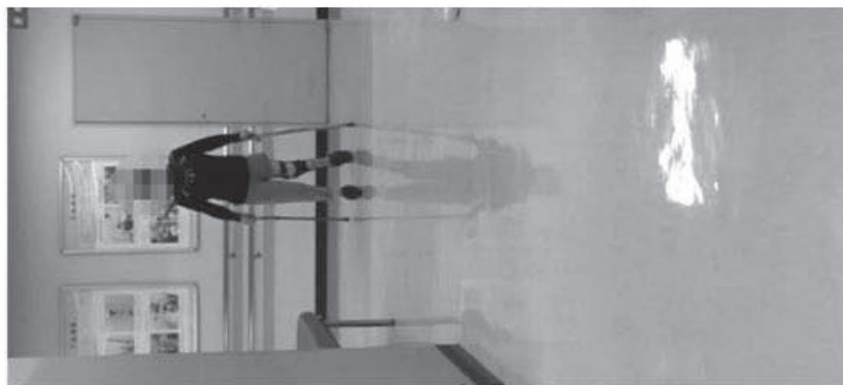
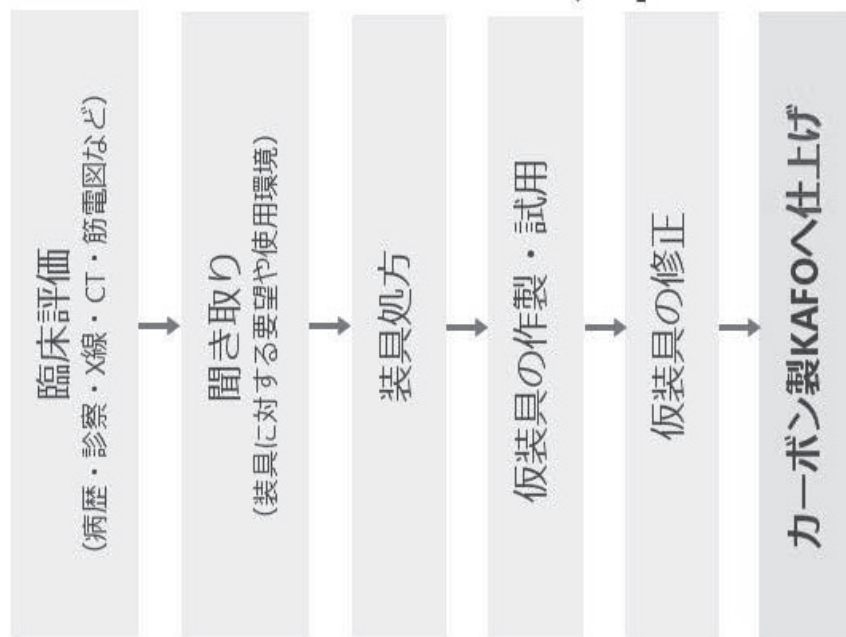
アクリル樹脂注入

# カーボン製KAFO 完成





# カーボン製KAFO 完成



- ・ 膝折れ，転倒がなくなった！
- ・ 歩行や立作業が楽になった！

	装具なし	装具あり
6MWT(m)	365	330
PCI	0.59	0.36 ↓

## カーボン製KAFOの適合をはかる 4つのポイント

1. 残存する機能を妨げない.
2. 患者の希望を優先する.
3. 脚長差補正は,  
1/3より開始し数年かけて2/3程度とする.
4. 仮装具において,  
十分に慣れる期間 (約1ヶ月) を設けて調整する.



上段：装具外来  
下段：リハビリテーション科専攻医の荒井義肢製作所見学

# F-MUNE自動解析プログラムにおける反復F波の自動同定に関する検証

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【目的】F-MUNEでは、反復F波を単一運動単位電位（SMUP）と解釈してMUNEを算出する。今回、我々が開発したF-MUNE自動解析プログラムで自動同定した反復F波について、手動同定およびMPS-MUNEと比較し、SMUPとして使用可能か検証した。【方法】ポリオのべ10手（正中神経5手・尺骨神経5手）で、F波（30%刺激強度、500回刺激）とMPS-MUNEを記録。F-MUNE自動解析プログラムの反復F波自動同定（自動群）と自動+手動同定（手動群）、MPS-MUNEのSMUPを比較した。【結果】反復F波の自動群と手動群の比較は、反復F波の種類（個）[自動群13.1（11.5）、手動群8.2（7.0）]（平均[中央値]）、総数（本）[64.1(58.5), 76.7(71.0)]と手動群では若干パラメータが変化するが、MUNE算出に用いる平均振幅（ $\mu\text{V}$ ）[174.0(141), 174.1(141.3)]は有意差がなく、F-MUNEへの影響は限定的と考えられた。また反復F波とMPS-MUNEのSMUPでは同一波形を認め、反復F波のSMUPとしての性質を支持する。【結論】F-MUNE自動解析プログラムで自動同定した反復F波は、SMUPとしてF-MUNEに使用可能である。

## はじめに

**MUNE**（motor unit number estimation）は電気生理学的な運動単位数推定法で、最大上刺激で記録したCMAP振幅を複数の**単一運動単位電位（SMUP: single motor unit potential）**の平均振幅で除して算出する。一方、F波は波形の多様性が特徴であるが、潜時・振幅・波形が同一なF波は**反復F波**と呼ばれ、SMUPと解釈することができる。今回我々は、反復F波を自動同定しSMUPとする**F-MUNE自動解析プログラム**を開発した。反復F波を自動同定するプログラムは、研究レベルで報告されるものの、現在実用化されているものない。

## 目的と方法

**目的：**F-MUNE自動解析プログラムの反復F波の自動同定を検証する。

**対象：**ポリオに伴う上肢弛緩性麻痺を呈するのべ10手（正中神経 [APB] 5手、尺骨神経 [ADM] 5手）

**方法：**F波（30%刺激強度、500回刺激）と**MPS-MUNE \***を計測する。F-MUNE自動解析プログラムの反復F波の**自動同定（自動群）**と**自動+手動同定（手動群）**、MPS-MUNEのSMUPを比較した。

\* MPS-MUNE（multiple point stimulation-MUNE）

## 結果

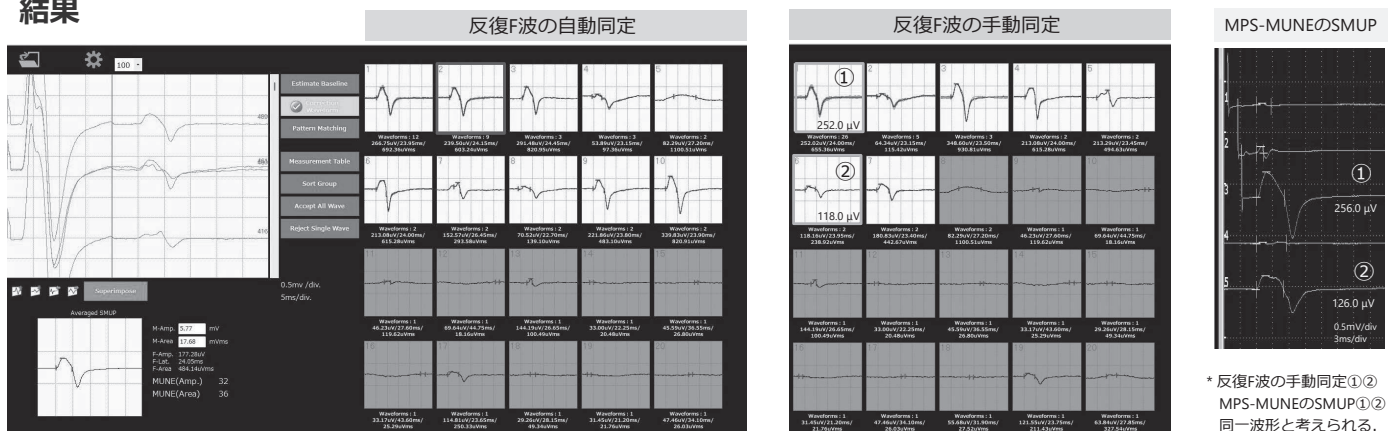


図1 F-MUNE自動解析プログラムと反復F波、MPS-MUNEとSMUP 解析例

n=10	反復F波の自動群	反復F波の手動群	P	MPS-MUNEのSMUP
反復F波の総数 (本/500回刺激)	58.5 (13.5-82.0)	71.0 (42.3-96.5)	*	—
反復F波/SMUP 種類 (個)	11.5 (2.75-19.0)	7.0 (5.3-10.0)		7.5 (7.0-9.25)
反復F波/SMUP 平均振幅 ( $\mu\text{V}$ )	141.3 (121.0-193.2)	198.6 (99.7-254.6)		76.3 (65.1-83.6)
MUNE	36.2 (29.9-54.0)	33.3 (28.3-50.2)		88.0 (53.8-153.0)

中央値 (IQR) 自動群と手動群の比較: Wilcoxon signed-rank test \*  $p < 0.05$

表1 SMUPとしてのパラメータ比較とMUNE (反復F波の自動群・手動群・MPS-MUNE)

## 結果まとめ・考察

- 同定した反復F波は、自動群と手動群で類似した特徴を持ち、MUNE算出に用いる平均振幅に有意差はなかった。また、MPS-MUNEと比較し、より多くの大きなSMUPを記録できた。
- 健康者を対象とするF波自動解析プログラムの研究では、反復F波は30%刺激強度で最も出現率が高い。Chroni E, et al.2017

## 結論

F-MUNE自動解析プログラムで自動同定した反復F波は、SMUPとしてF-MUNEに使用可能である。

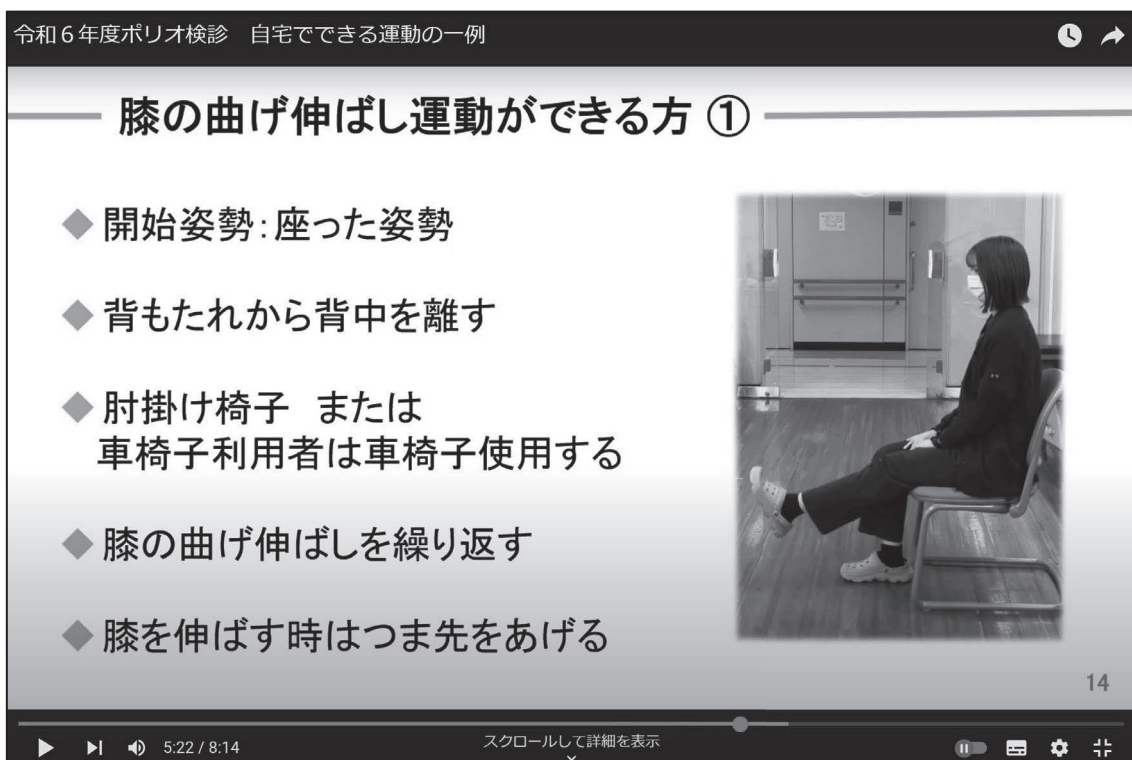
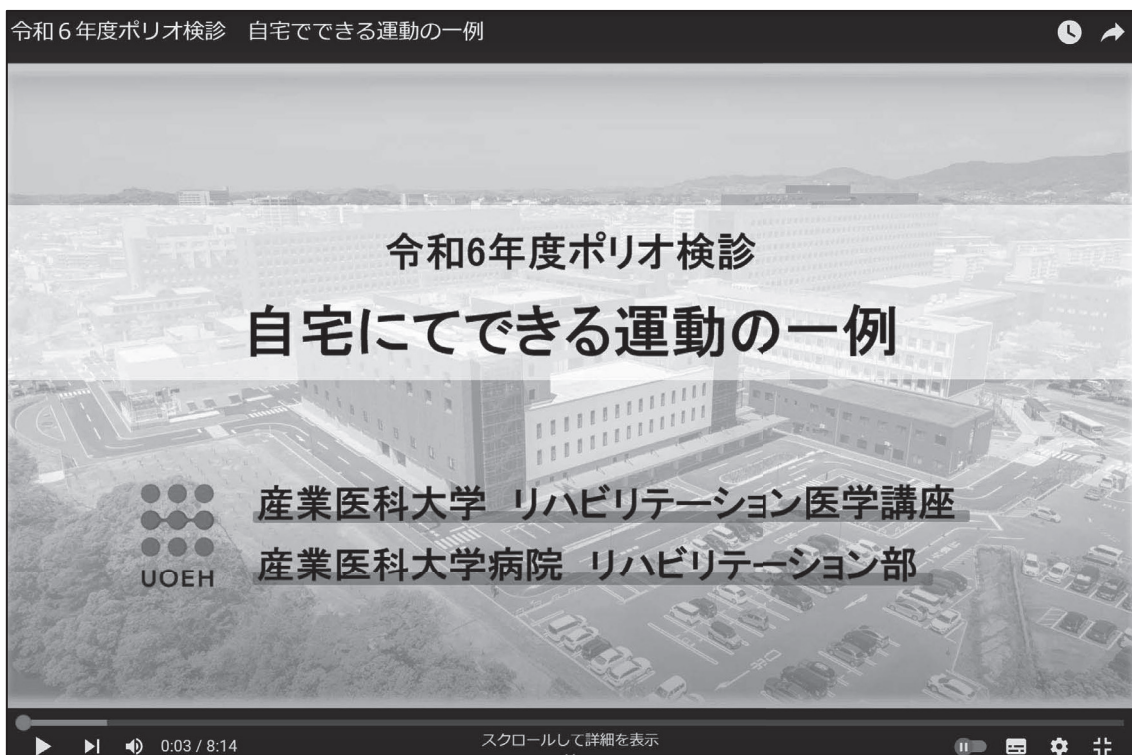
蜂須賀明子：演題発表に関連し、開示すべきCOI関係にある企業などはありません

図2 反復F波の手動同定の手順例（自動同定 No2波形より）



## 【別紙資料 23】

ポリオ検診 自宅でできる運動の一例（産業医大公式 YouTube チャンネル）





# Impact of Presarcopenic Dysphagia on 1-Year Mortality After Videofluoroscopic Swallowing Study in Patients with Cancer

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Received: 3 July 2023 / Accepted: 26 November 2023

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## Abstract

Sarcopenic dysphagia is the term for swallowing difficulty associated with loss of mass, strength, and physical performance, which leads to increased pharyngeal residues. Unlike sarcopenia, presarcopenia is characterized by low muscle mass without decreased muscle strength or physical performance and can develop into dysphagia due to low skeletal muscle mass. This retrospective study investigated the impact of presarcopenic dysphagia (PSD) on 1-year mortality in patients with cancer and dysphagia who underwent a videofluoroscopic swallowing study (VFSS). An operational definition of PSD based on presarcopenia and pharyngeal residues was adopted. The psoas muscle mass index ( $\text{cm}^2/\text{height} [\text{m}^2]$ ), calculated by the psoas muscle area at the third lumbar vertebra via abdominal computed tomography (CT) and related to height, was used to assess presarcopenia with cutoff values of 4.62 for men and 2.66 for women. Pharyngeal residues were assessed using a VFSS to evaluate dysphagia. Patients' medical charts were analyzed to investigate 1-year mortality after a VFSS. Out of 111 consecutive patients with cancer, 53 (47.7%) were defined as having PSD. In a forward-stepwise Cox proportional regression analysis, PSD (HR 2.599; 95% CI 1.158–5.834;  $p=0.021$ ) was significantly associated with 1-year mortality after a VFSS, even after adjusting for the factors of operation, Functional Oral Intake Scale (FOIS) scores at discharge, and modified Barthel Index (BI) scores at discharge. PSD, defined as CT-based presarcopenia and pharyngeal residues observed during a VFSS, is associated with increased 1-year mortality in patients with cancer and dysphagia.

**Keywords** Sarcopenia · Presarcopenia · Dysphagia · Cancer · Mortality · Videofluoroscopic swallowing study

## Introduction

Sarcopenia, which occurs with aging, interferes with muscle function. Some persons with low skeletal muscle mass experience a decline in swallowing function, a condition known as sarcopenic dysphagia. Sarcopenic dysphagia, thus, develops from decreased strength of the swallowing muscles and reduced swallowing muscle mass associated with low skeletal muscle mass of the whole body [1]. The global prevalence of sarcopenia in patients with cancer is approximately 38% [2], with a risk of mortality [3]. Furthermore, the prevalence of dysphagia is about 54% in patients with

cancer undergoing surgery, chemotherapy, or radiotherapy [4]. However, sarcopenic dysphagia's impact on mortality in cancer patients remains unknown.

Clear diagnostic criteria have not been defined for sarcopenic dysphagia. Nevertheless, Fujishima et al. [1] reported that dysphagia due to low skeletal muscle mass could cause pharyngeal residues, characteristic of sarcopenic dysphagia. In a videofluoroscopic swallowing study (VFSS), older people showed decreased pharyngeal wall thickness [5], and enlargement of the pharyngeal area was observed during VFSS in patients with sarcopenia [6]. These findings are associated with increased pharyngeal residues due to low skeletal muscle mass and sarcopenia.

Presarcopenia is characterized by low skeletal muscle mass without decreased muscle strength or physical function [7], which differs from sarcopenia. In patients with cancer, presarcopenia is approximately 58% [8], and the prognosis for presarcopenia is as unfavorable as that for sarcopenia [9, 10]. Furthermore, presarcopenia, like sarcopenia, can

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cause dysphagia due to low skeletal muscle mass. The psoas muscle mass index ( $\text{cm}^2/\text{height}^2$  [ $\text{m}^2$ ]), calculated using the psoas muscle's mass area at the third lumbar vertebra (L3) and height via abdominal computed tomography (CT), has been used to diagnose presarcopenia in patients with cancer [9–11]. CT is frequently used in oncology to determine the spread of cancer, the effectiveness of treatment, and whether cancer has metastasized to other organs. Thus, it is easy to assess skeletal muscle mass and define presarcopenia in patients with cancer without additional examinations.

Therefore, in this study, we adopted the operational definition of presarcopenic dysphagia (PSD) by CT-based presarcopenia and pharyngeal residues for patients with cancer who had undergone VFSS. This study aimed to investigate the impact of PSD on mortality in patients with cancer.

## Methods

### Study Design and Participants

This retrospective cohort study included 277 patients with cancer and dysphagia who underwent VFSS at the University Hospital of Occupational and Environmental Health, Japan, between September 2009 and November 2021. The inclusion criteria were patients who had undergone invasive treatments such as surgery, chemotherapy, and radiotherapy in the hospital and an abdominal CT within 90 days before or 30 days after VFSS for clinical reasons. This study excluded

patients with acute stroke onset in the hospital, neurological disorders, brain tumors, or head and neck cancer who were ineligible for sarcopenic dysphagia in a previous study [1]. Additionally, patients with missing data, primary cancer of unknown origin, and who underwent pharyngolaryngoesophagectomy, VFSS after the first two-stage operation, and synchronous surgical resection of double cancer were also excluded (Fig. 1).

#### Definition of presarcopenic dysphagia

Patients with CT-based presarcopenia and pharyngeal residues who underwent VFSS were defined as patients with PSD.

### Assessment of Skeletal Muscle Mass and Presarcopenia

The psoas muscle mass index was calculated by measuring the cross-sectional area of the left and right psoas muscles at the L3 via abdominal CT performed closest to the VFSS date. Muscle mass was quantified by Hounsfield unit ranging from  $-29$  to  $+150$ . The psoas muscle area was automatically measured by dragging on the target muscle using the Shad-eQuest software (ViewRV1.29; FUJIFILM Medical Solution Corporation, Tokyo, Japan) (Fig. 2). The cutoff values of the psoas muscle mass index for low skeletal muscle mass were  $4.62 \text{ cm}^2/\text{m}^2$  for men and  $2.66 \text{ cm}^2/\text{m}^2$  for women, according to a previous report [12]. Low skeletal muscle mass was defined as presarcopenia.

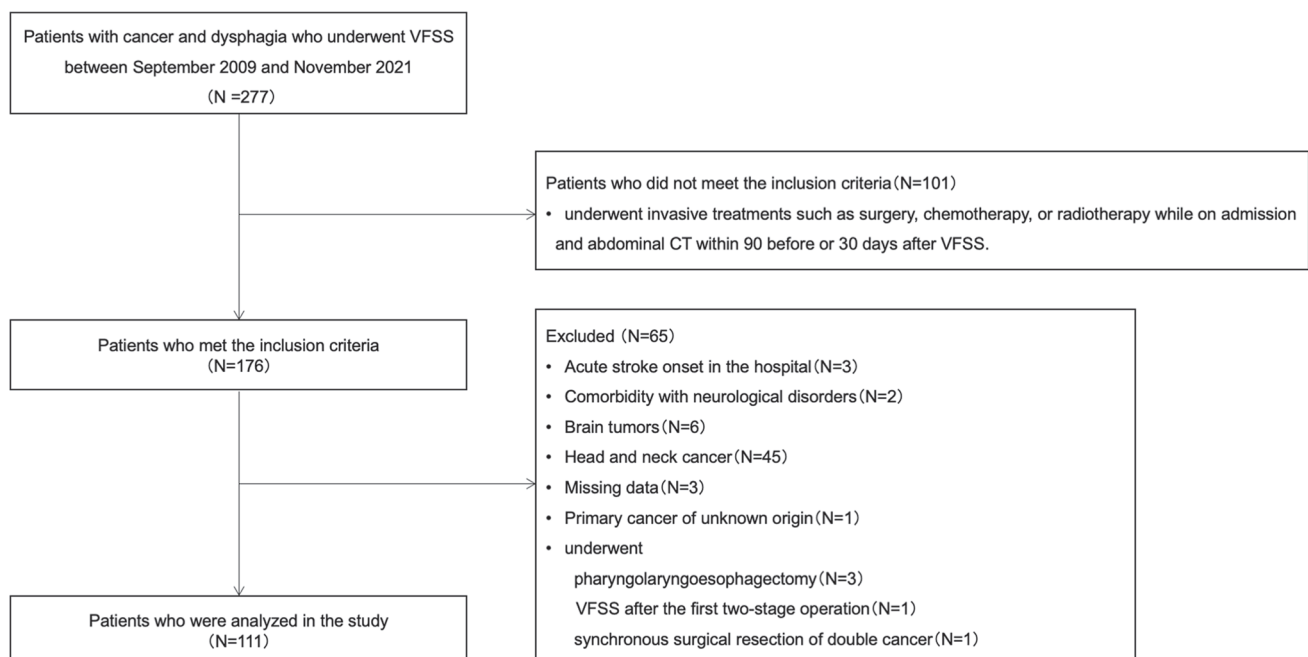
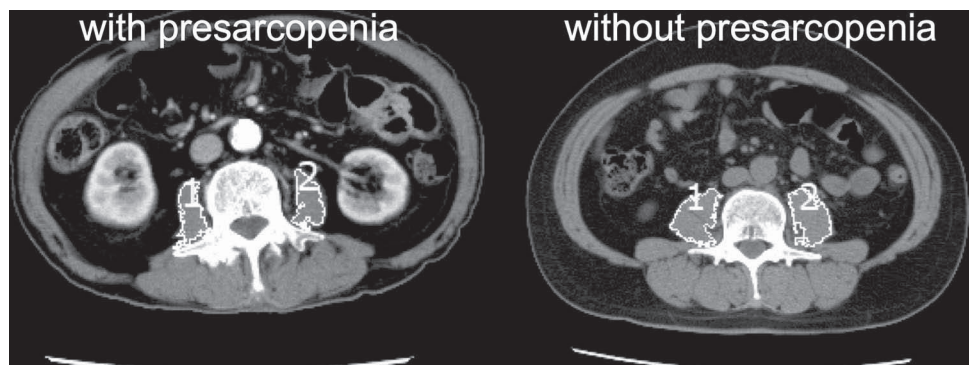


Fig. 1 Study flowchart



**Fig. 2** Psoas muscle's mass area (1 + 2) at the third lumbar vertebra was identified in patients with and without presarcopenia

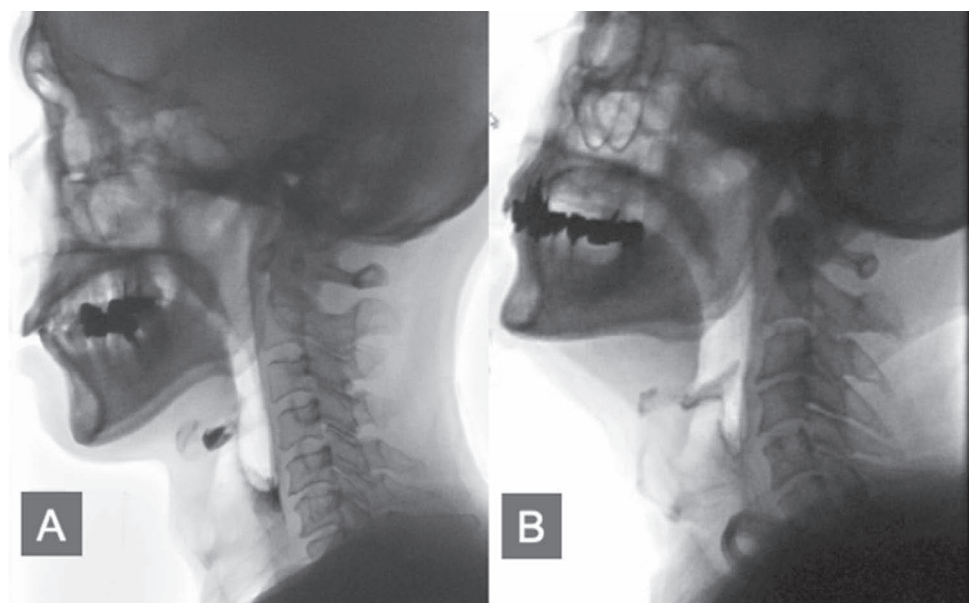


### Videofluoroscopic Swallowing Study Findings

The objective of VFSS, performed by physiatrists, was to assess the detailed swallowing function of patients diagnosed with dysphagia based on abnormal findings from screening tests and other symptoms such as choking during meals or discontinuation of eating or drinking. Patients' swallowing movements were monitored during VFSS while they consumed food containing barium under fluoroscopy (Fig. 3). The patients were conscious throughout the procedure. They consumed various food items, including jelly, thickened liquid, water, dysphagia diet items, and rice with barium, while sitting or reclining at approximately 45°, with most patients sitting. Dysphagia diet items are formulated to be easily formed into food boluses, even for individuals with missing teeth or dental appliances. They exhibit minimal oral residue during consumption, have good cohesiveness, and do not disintegrate quickly upon passage through the pharynx. The standardized evaluation form used by physiatrists included

assessments of oral, pharyngeal (including vallecula and pyriformis), and esophageal phases, such as chewing and bolus formation in the oral phase, time to induce reflex deglutition, vallecular and pyriform residues, penetration, and aspiration in the pharyngeal phase, and esophageal residues and reflux in the esophageal phase. Vallecular and pyriform residues were considered pharyngeal residues during VFSS, and the residues were evaluated when they remained after a single swallow. Pharyngeal residues consisted of vallecular and/or pyriform residues. The physiatrists recorded the results on patients' medical charts on the day of VFSS. Each VFSS was recorded on a DVD, which was reviewed as necessary. Although some patients underwent VFSS multiple times, assessments from the initial VFSS were used for analyses. This study also examined whether nasogastric tubes or tracheal cannulas were used. While a cuffed tracheal cannula was standard, it was not systematically verified whether the cuff was inflated during each VFSS.

**Fig. 3** Videofluoroscopic swallowing study findings. **A** Pharyngeal residues were observed after swallowing a dysphagia diet in a patient with presarcopenia. **B** No pharyngeal residue was observed after swallowing a dysphagia diet in a patient without presarcopenia



## Other Parameters

This study investigated 1-year mortality after VFSS based on the medical charts. If a patient was lost to follow-up, the last follow-up was defined as the most recent clinical visit date. Activities of daily living (ADL) were assessed using the modified Barthel Index (BI) at admission and discharge. The modified BI divides two items, dressing and transferring to and from a toilet, from the Barthel Index [13] into the upper and lower dressing, and transferring to and from a toilet, bed, and bathtub, respectively. The modified BI has a total score of 100; the higher the scores, the better the ADL. It consists of 13 items: (1) feeding; (2) grooming; (3) and (4) upper and lower dressing; (5), (6), and (7) transferring to and from a toilet, bed, and bathtub; (8) and (9) bladder and bowel management; (10) toileting; (11) bathing; (12) walking; and (13) climbing up and down.

The severity of dysphagia was assessed at admission, VFSS, and discharge using the Functional Oral Intake Scale (FOIS) [14]. Pneumonia was evaluated when the following criteria were met: alveolar infiltration on chest X-ray or CT; at least two episodes of fever  $\geq 37.5$  °C, abnormally high C-reactive protein levels, peripheral white blood cell count  $\geq 9000/\mu\text{L}$  or airway symptoms such as the presence of sputum. Rehabilitation intervention at the bedside or gymnasium was prescribed for most patients. Speech therapy was conducted in 20- to 40-min swallowing training sessions by a speech therapist, depending on the patient's condition, using a combination of indirect swallowing training that did not involve food or drink, such as muscle strengthening around the mouth, chewing, tongue posture, Mendelsohn maneuvers, and head elevation, and direct swallowing training that involved food and drink, such as neck rotation, supraglottic swallow, multiple swallowing, alternating swallowing, and bite-size adjustments. Physical and occupational therapists also provided physical and occupational therapy involving resistance, motion, or gait training.

The cancer categories were esophageal cancer and others. Cancer staging was performed using the tumor, nodes, and metastasis (TNM) classification. Patients were diagnosed with recurrent laryngeal nerve palsy when they had surgical recurrent laryngeal nerve resection or when endoscopic findings confirmed it. Treatments underwent in the hospital were classified as operation, chemotherapy, and radiotherapy. The Charlson Comorbidity Index was used to determine the degree of comorbidities [15]. Body mass index (BMI), speech therapy days during the hospital, days from admission to VFSS, VFSS to discharge, and abdominal CT to VFSS, and length of hospital stay were investigated. The discharge destinations were classified as a home, another hospital, and death in the hospital.

## Statistical Analyses

Based on a previous study [16], where the 3-year mortality rates in patients with and without sarcopenic dysphagia (51 vs. 44) in a nursing home were 41.2% and 20.5%, respectively, the sample size was calculated using the free-ware EZR version 1.10 [17] with  $\alpha=0.05$  and power=0.8, requiring at least 65 and 75 patients in each group to detect 1-year mortality using a multivariate Cox proportional hazards regression. All statistical analyses were performed using SPSS Version 27 software (IBM SPSS Japan, Tokyo, Japan). Statistical significance was set at a two-tailed *p*-value of  $<0.05$ . Categorical variables were described as the number of patients (percentage). Quantitative variables, including parametric and nonparametric, were described as mean (standard deviation) and median [interquartile range, 25–75th percentiles], according to normal and non-normal distributions based on the Shapiro–Wilk test. Patients with and without PSD were compared using the Chi-squared and Fisher's exact tests for categorical variables and the *t*-test and Mann–Whitney U test for quantitative variables. Survival time was calculated as the number of days from VFSS to the 1-year follow-up. A forward-stepwise Cox proportional hazards regression analysis was performed with all variables as independent variables except the discharge destination. The TNM classification was divided into IV vs. I–III. The Charlson Comorbidity Index was divided into 0 vs.  $\geq 1$ . Additionally, Kaplan–Meier 1-year survival curves were generated for patients with and without PSD, and the log-rank test was performed to test for differences in survival distributions.

## Results

Of 277 patients screened for eligibility, 111 (83.7% men) were analyzed in the study. The cancer categories were as follows: esophageal ( $n=50$ ) and others ( $n=61$ ); lung ( $n=40$ ), colon ( $n=4$ ), gastrointestinal ( $n=3$ ), biliary tract ( $n=3$ ), hepatocellular ( $n=2$ ), uterine ( $n=2$ ), malignant pleural mesothelioma ( $n=2$ ), pancreatic ( $n=1$ ), duodenal ( $n=1$ ), breast ( $n=1$ ), bladder ( $n=1$ ), and mediastinal ( $n=1$ ). Operation cases were as follows: esophageal ( $n=40$ ), lung ( $n=18$ ), colon ( $n=4$ ), biliary tract ( $n=3$ ), gastric ( $n=2$ ), hepatocellular ( $n=2$ ), malignant pleural mesothelioma ( $n=2$ ), duodenal ( $n=1$ ), and pancreatic ( $n=1$ ). The 73 patients had undergone surgery, and all of them underwent VFSS postoperatively. Speech therapy, physical therapy, and occupational therapy were performed in 91, 97, and 3 patients, respectively. Eighty-three (74.7%) patients had CT-based presarcopenia, and 67 (60.3%) patients had pharyngeal residues. A total of 53 patients (47.7%) were defined as PSD.

Table 1 presents comparisons between patients with and without PSD. There were more men patients with PSD ( $p=0.004$ ) than those without PSD. During VFSS, patients with PSD had significantly more vallecular, pyriform, and pharyngeal residues and aspiration ( $p<0.001$ , respectively). Furthermore, patients with PSD had significantly lower FOIS scores at VFSS and discharge ( $p=0.032$  and  $p=0.038$ , respectively). Patients with PSD also had significantly lower modified BI scores ( $p=0.009$ ). BMI at admission and discharge were significantly lower in patients with PSD ( $p<0.001$ ). Pneumonia was more common in patients with PSD ( $p=0.044$ ). Days from admission to VFSS were more prolonged in patients with PSD ( $p=0.047$ ), and their discharge destination ( $p=0.002$ ) was another hospital or death in the hospital.

A total of 58 patients completed follow-ups for 1-year after VFSS. Eleven patients were lost to the follow-up process. Death was confirmed in 31 patients (27.9%), 20 with PSD and 11 without PSD. In the forward-stepwise Cox proportional regression analysis, PSD (hazards ratio (HR): 2.599; 95% confidence interval (CI): 1.158–5.834;  $p=0.021$ ), operation (HR: 0.224; 95% CI: 0.105–0.479;  $p<0.001$ ), FOIS scores at discharge (HR: 0.77; 95% CI: 0.64–0.95;  $p=0.015$ ), and modified BI scores at discharge (HR: 0.977; 95% CI: 0.964–0.99;  $p<0.001$ ) were significant predictors of 1-year mortality after VFSS (Table 2). Multicollinearity was not observed among the variables. The mean survival time was longer in patients without PSD than those with PSD (325 days; 95% CI: 302–347 vs. 243 days; 95% CI: 201–284). The survival distributions differed significantly between patients with and without PSD ( $\chi^2$ : 8.73;  $p=0.003$ ). The survival curves for patients with and without PSD are shown in Fig. 4.

## Discussion

This study showed that PSD, defined by CT-based presarcopenia and pharyngeal residues assessed by VFSS, was associated with an increased risk of 1-year mortality in patients with cancer and dysphagia. To the best of our knowledge, this is the first study to demonstrate the association between 1-year mortality in cancer patients with PSD based on abdominal CT and VFSS findings.

In this study, more than half of patients with cancer and dysphagia had CT-based presarcopenia and pharyngeal residues during VFSS. We could estimate that many patients had presarcopenia and dysphagia with pharyngeal residues simultaneously because the prevalence of presarcopenia and dysphagia surpasses 50% for each in patients with cancer, consistent with previous reports [4, 8]. The prevalence of PSD in this study was 47%; suggesting that many patients with cancer had PSD.

Sarcopenia dysphagia is defined as dysphagia compounded by the presence of sarcopenia [1, 18]. Presarcopenia and sarcopenia are typically diagnosed by assessing grip strength, skeletal muscle mass, and physical function. Additionally, presarcopenia and sarcopenia may also be evaluated based on the psoas muscle mass index [9–11, 19–21]. On the other hand, some reports evaluate swallowing function using the Viscosity swallowing test [22] and FOIS and define sarcopenia dysphagia based on these assessments [16, 23]. However, the distinctive feature of dysphagia developed from decreased strength of the swallowing muscle and reduced swallowing muscle mass associated with low skeletal muscle mass calls for increased pharyngeal residues. No reports have been of diagnosing sarcopenia dysphagia based on assessments of pharyngeal residues using VFSS or endoscopy. Our study employs a unique perspective by postulating that the decline in skeletal muscle mass and the atrophy of specific swallowing muscles leads to increased pharyngeal residues. We have primarily focused on this aspect and our operational definition of PSD by abdominal CT and VFSS. Furthermore, our approach adopted lower cutoff values compared to the conventional assessment of sarcopenia based on the psoas muscle mass index [19–21]. As a result, PSD, by our operational definition, which relates closely to the features of sarcopenia dysphagia, may indicate the potential presence of dysphagia due to pharyngeal muscle atrophy associated with reduced skeletal muscle mass. Therefore, our study indicates that PSD in patients with cancer and dysphagia increases the 1-year mortality following VFSS. Additionally, sarcopenic dysphagia may further elevate the mortality risk in patients with cancer. Our study suggests that sarcopenia dysphagia in cancer patients may increase the 1-year mortality rate following VFSS.

This study indicates that the operation, FOIS scores at discharge, and modified BI scores at discharge were prognostic factors of 1-year mortality. Patients who underwent surgery were considered not to have contributed to the increased 1-year mortality because they had an earlier cancer stage and better physical condition than inoperable patients. Difficulty in swallowing arises from malnutrition, which is associated with mortality in patients with cancer [24, 25]. Moreover, low ADL increases mortality in patients with cancer [26–28]. Therefore, the findings that low FOIS and modified BI scores at discharge increased 1-year mortality in the present study are consistent with previous studies.

In this study, we introduced a new definition of PSD in patients with cancer and dysphagia and clarified the relationship between PSD, mortality, and prognostic factors. This new PSD definition utilizes the VFSS and CT scan that cancer patients routinely undergo to evaluate dysphagia, is easy to introduce into clinical practice, and may become highly clinically significant. This differs from the definition of sarcopenic dysphagia made using expensive body composition

**Table 1** Comparison between patients with and without presarcopenic dysphagia

	With PSD <i>n</i> = 53	Without PSD <i>n</i> = 58	<i>p</i> -value
Presarcopenia, <i>n</i> (%)	53 (100%)	30 (51.7%)	<0.001
PMI, cm <sup>2</sup> /m <sup>2</sup> , mean (SD)	3.24 (0.69)	4.28 (1.37)	<0.001
Age, years, median [IQR]	73.3 [67.4, 79.3]	70.5 [63.8, 75.9]	0.077
Men, sex, <i>n</i> (%)	50 (94.3%)	43 (74.1%)	0.004
Treatment			
Operation, <i>n</i> (%)	37 (69.8%)	36 (62%)	0.391
Chemotherapy, <i>n</i> (%)	8 (15%)	15 (25.8%)	0.162
Radiotherapy, <i>n</i> (%)	12 (22.6%)	11 (18.9%)	0.633
Cancer category			0.139
Esophageal, <i>n</i> (%)	20 (37.7%)	30 (51.7%)	
Others, <i>n</i> (%)	33 (62.2%)	28 (48.2%)	
Cancer stage, TNM, <i>n</i>			0.903
I	7 (13.2%)	10 (17.2%)	
II	13 (24%)	13 (22.4%)	
III	18 (33.9%)	21 (36.2%)	
IV	15 (28.3%)	14 (24.1%)	
CCI, <i>n</i>			0.145
0	23 (43%)	30 (51.8%)	
≥1	30 (57%)	28 (48.2%)	
Recurrent laryngeal nerve palsy, <i>n</i> (%)	12 (22.6%)	21 (36.2%)	0.118
FOIS			
At admission, median [IQR]	7 [7]	7 [7]	0.702
At VFSS, median [IQR]	2 [1, 5]	4 [1, 6]	0.032
At discharge, median [IQR]	5 [4, 7]	6 [5, 7]	0.038
Modified BI			
At admission, scores, median [IQR]	100 [77, 100]	100 [90, 100]	0.166
At discharge, scores, median [IQR]	75 [29, 100]	93 [70, 100]	0.009
VFSS findings			
Nasogastric tube, <i>n</i> (%)	7 (13.2%)	4 (6.8%)	0.266
Tracheal cannula, <i>n</i> (%)	8 (15%)	3 (5.1%)	0.081
Vallecular residues, <i>n</i> (%)	47 (88.6%)	14 (24.1%)	<0.001
Pyriform residues, <i>n</i> (%)	39 (73.5%)	6 (10.3%)	<0.001
Pharyngeal residues, <i>n</i> (%)	53 (100%)	14 (24.1%)	<0.001
Aspiration, <i>n</i> (%)	31 (58.4%)	11 (18.9%)	<0.001
BMI			
At admission, kg/m <sup>2</sup> , mean (SD)	19.7 (2.6)	21.8 (3.8)	<0.001
At discharge, kg/m <sup>2</sup> , mean (SD)	17.7 (2.4)	19.6 (3.4)	<0.001
Pneumonia in hospital, <i>n</i> (%)	33 (62.2%)	25 (43.1%)	0.044
Speech therapy days, median [IQR]	13 [5, 19]	8 [2, 18]	0.106
Length of hospital stay, days, median [IQR]	45 [32, 73]	46 [24, 68]	0.293
Days from admission to VFSS, median [IQR]	22 [16, 41]	18 [12, 27]	0.047
Days from VFSS to discharge, median [IQR]	19 [9, 33]	18 [9, 47]	0.841
Days from VFSS to abdominal CT, median [IQR]	−26 [−37, −10]	−20 [−38, −9]	0.728
Discharge destination, <i>n</i> (%)			0.002
Home	20 (37.7%)	36 (62%)	
Another hospital	26 (49%)	22 (37.9%)	
Death in the hospital	7 (13.2%)	0 (0%)	

The categorical variables were described as the number of patients (percentage)

The quantitative variables were mean (SD, standard deviation) and median [IQR, interquartile range, 25–75th percentiles]

Pharyngeal residues consisted of vallecular and/or pyriform residues

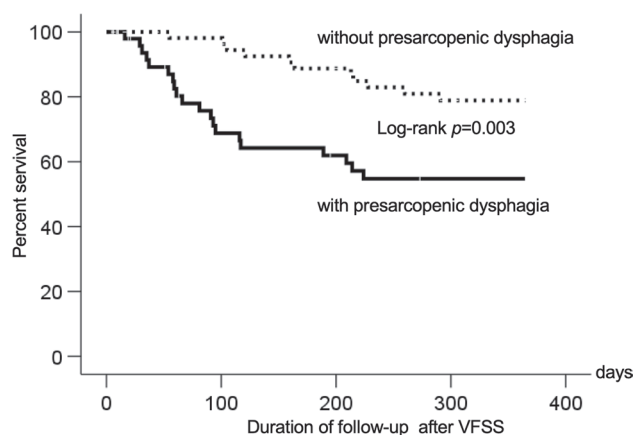
*PSD* presarcopenic dysphagia, *PMI* psoas muscle mass index, *TNM* tumor, nodes, and metastasis, *CCI* Charlson Comorbidity Index, *FOIS* Functional Oral Intake Scale, *VFSS* videofluoroscopic swallowing study, *BI* Barthel Index, *BMI* body mass index, *CT*, computed tomography



**Table 2** Presarcopenic dysphagia as a predictor of 1-year mortality after a videofluoroscopic swallowing study in a forward-stepwise Cox regression analysis

	HR	95% CI	<i>p</i> -value
PSD	2.599	1.158 – 5.834	0.021
Operation	0.224	0.105 – 0.479	<0.001
FOIS scores at discharge	0.77	0.64 – 0.95	0.015
Modified BI scores at discharge	0.977	0.964 – 0.990	<0.001

PSD presarcopenic dysphagia, VFSS videofluoroscopic swallowing study, HR hazard ratio, CI confidence interval, FOIS Functional Oral Intake Scale, BI Barthel Index

**Fig. 4** Kaplan–Meier 1-year survival curves for patients with presarcopenic dysphagia

equipment to evaluate skeletal muscle mass of the whole body or imaging studies such as CT, MRI, or echo to evaluate swallowing muscle mass.

Our study underscores the intricate connection between dysphagia, pneumonia, cancer, and immunosuppression. Dysphagia in cancer patients is affected by various factors, such as presarcopenia, recurrent laryngeal nerve palsy, cancer treatments, surgery. It may heighten pneumonia risk, but the precise causative link remains unclear. However, our study acknowledges these multifaceted influences and focuses on presarcopenia's role in dysphagia due to low skeletal muscle mass, necessitating further investigation.

This study has some limitations. First, this was a single-center study; hence, the results do not necessarily reflect a generalized conclusion that a multicenter study might achieve. Second, the study did not measure grip strength and physical performance to diagnose presarcopenia. Third, all patients underwent VFSS under different conditions regarding the variety and amount of food ingested. Water was often applied with a 1–3 ml spoon, and food with a teaspoonful. Pharyngeal residues were more likely with dense foods and larger quantities. The evaluation needed more specifics about residual amounts, possibly affecting the findings. Typically,

in VFSS, there should be no pharyngeal residues after a single swallow, making any residue abnormal. Thus, there might be differences in the easy-to-detect VFSS findings between patients. Future studies should standardize the variety and amount of food ingested for evaluation consistency. Fourth, while esophageal cancer cases were prevalent in our study, our findings also highlight PSD in patients with other cancer types. Further research across different cancer categories is needed to clarify the relationship between presarcopenia and dysphagia. Finally, the impact of treatment on muscle wasting could not be eliminated because of the period from VFSS to abdominal CT when assessing skeletal muscle mass.

## Conclusion

This study found that PSD, defined by CT-based presarcopenia and pharyngeal residues observed during VFSS, increased the 1-year mortality in patients with cancer and dysphagia. Further investigation is warranted to improve prognosis through nutritional therapy and swallowing training interventions in patients with PSD.

**Author Contributions** TM conceived the idea of the study, developed the statistical analyses, and drafted the original manuscript on intellectual content. AH and YM contributed to interpreting the results and revised the original manuscript. MT, RH, HT, HI, and MO contributed to collecting the data for the study. SS supervised the conduct of the study. All Authors reviewed the manuscript draft and approved publishing the final version.

**Funding** This study was not financially supported.

**Data Availability** All data are not publicly available owing to opt-out restrictions. Data sharing is not applicable.

## Declarations

**Conflict of Interests** The authors declare no conflict of interest.

**Ethical Approval** This study was conducted under the Declaration of Helsinki and with the approval of the Ethics Committee of the University Hospital of Occupational and Environmental Health, Japan [UOE-HCRB22-144]. Written informed consent was not obtained because of the retrospective observational nature of the study. Nevertheless, all patients were allowed to provide an opt-out option to withdraw from the study at any time.

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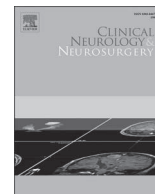
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## Low phase angle is associated with swallowing outcomes in patients with acute stroke

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### ARTICLE INFO

#### Keywords:

Phase angle  
Skeletal muscle mass  
Sarcopenia  
Dysphagia  
Acute stroke

### ABSTRACT

**Background and purpose:** Stroke-induced dysphagia is a critical complication that can lead to severe secondary worldwide health issues. This retrospective cohort study investigated the association between phase angle (PhA) and swallowing function in the acute phase of stroke. We aim to establish whether nutritional and muscular interventions associated with PhA could enhance swallowing recovery and reduce related risks post-stroke.

**Methods:** Stroke patients requiring rehabilitation were assessed for the association between low PhA—with cutoff values for low PhA defined as less than 5.28 for men and 4.32 for women—and swallowing function using a functional oral intake scale (FOIS) on Day 7 after admission and after the completion of acute stroke treatment.

**Results:** In this study of 140 acute stroke patients (median age 74[69–81], and 85 men and 55 women), 76 patients with low PhA significantly exhibited older age, lower body mass index, more decline in skeletal muscle mass index, and lower pre-morbid modified Rankin Scale scores compared to 64 patients with high PhA. Multivariate linear regression revealed that low PhA was independently associated with FOIS scores on Day 7 after admission ( $\beta=-0.143$  and  $p=0.036$ ) and after the completion of acute stroke treatment ( $\beta=-0.513$  and  $p=0.024$ ), even when adjusting for confounding factors.

**Conclusions:** Low PhA is associated with swallowing function in patients with acute stroke. Nutritional and physical interventions improving PhA may lead to a reduction of the risk associated with stroke sequelae.

### 1. Introduction

Stroke is a leading cause of disability worldwide, leaving survivors with a range of long-term complications [1]. Swallowing difficulties are a common consequence of stroke that can lead to severe complications such as pneumonia and malnutrition [2,3]. The importance of assessing and managing swallowing functions in stroke treatment cannot be overstated, as early intervention can significantly reduce the risk of secondary complications.

Patients who have experienced a stroke and exhibit low muscle mass or sarcopenia may face challenges in recovering their swallowing ability during the acute or subacute phase [4–7], placing them at a heightened risk of undernutrition. These findings indicate that nutritional and muscle status is linked to the recovery of swallowing function after a stroke, highlighting the critical need for interventions in nutrition and physical rehabilitation early in the stroke phase.

Phase angle (PhA) is a non-invasive, low-cost medical indicator that

measures cellular robustness by sending a small electrical current throughout the body using bioelectrical impedance analysis (BIA), with an elevated PhA indicating superior physiological efficiency and structural strength [8,9]. PhA is associated with both nutritional [10] and skeletal muscle status [11], as well as with sarcopenia following a stroke [12]. Additionally, there is an association between PhA and swallowing function in the subacute phase [13]. The relationship between PhA and swallowing function suggests that improving nutritional and muscle status is essential in treating dysphagia during acute stroke treatment, which may lead to a reduction in the risks associated with stroke sequelae. However, the relationship between PhA and swallowing function in acute stroke remains unclear.

Here, we present the results of the association between PhA and swallowing function in the acute stroke phase. This study is significant because it suggests that improved nutritional and muscle status, as reflected by PhA, could enhance swallowing function in patients with acute stroke.

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<https://doi.org/10.1016/j.clineuro.2024.108388>

Received 22 May 2024; Accepted 9 June 2024

Available online 12 June 2024

0303-8467/© 2024 Published by Elsevier B.V.

## 2. Materials and methods

### 2.1. Study and setting

This retrospective cohort study was conducted at the University Hospital of Occupational and Environmental Health between February 2022 and March 2024. Patients admitted within seven days of acute ischemic or hemorrhage onset, requiring rehabilitation, were included. Acute stroke was confirmed using computed tomography or magnetic resonance imaging. Exclusion criteria included patients discharged within seven days post-admission; those who were missing data; underwent craniotomy; had lateral medullary syndrome, bilateral hemiplegia, comorbidities of neuromuscular disease, or were on hemodialysis; unable to perform BIA due to conditions such as pacemaker implantation; died during hospitalization; transferred to another department because of complications; or exhibited severe dysphagia, indicated by a premorbid functional oral intake scale (FOIS) score of less than 5 [14].

### 2.2. Body composition

PhA calculation was conducted after 10 minutes of rest and at least 2 hours post-prandial; patients were lying positioned for the application of a 200- $\mu$ A current at frequencies of 5, 50, and 250 kHz using the InBody S10 device (InBody Japan, Tokyo, Japan), which measured PhA and skeletal muscle mass at rehabilitation start. PhA was calculated from the impedance values of the right half of the body at 50 kHz using the following equation:  $\arctangent(X/R) \times (180/\pi)$ , where X is the reactance, and R is the resistance [12]. Skeletal muscle mass index (SMI) was calculated by dividing the measured appendicular skeletal muscle mass by the squared height in meters. According to the previous report [12], the cutoff values for low PhA were  $<5.28$  in men and  $<4.32$  in women. Patients were categorized into high and low PhA groups.

### 2.3. Swallowing function assessment

Swallowing function was assessed using the modified Water Swallowing Test (MWST) by stroke neurologists, physiatrists, or speech therapists before starting rehabilitation post-admission. Patients with a Japan Coma Scale score of 10 or higher [15] skipped the swallowing evaluation before rehabilitation and started eating based on the swallowing evaluation after they became conscious. The MWST involves swallowing 3 ml of cold water to evaluate the risk of aspiration [7,16], with scoring from 1 to 5: 1 for unable to swallow, 2 for swallowing with respiratory distress, 3 for coughing or wet voice after swallowing, 4 for no cough after swallowing, and 5 for the ability to swallow twice consecutively without coughing or wet voice. Swallowing screening results, pre-stroke dietary habits, and dental status were considered in determining the appropriate dietary form. The dietary form was evaluated using FOIS [14]. The FOIS is a reliable assessment scale for evaluating swallowing function in stroke patients. It includes a seven-point scale ranging from 1, indicating "nothing by mouth," to 7, indicating "total oral intake with no restrictions." The scale details are as follows: 1 represents "nothing by mouth"; 2 signifies "tube-dependent with minimal attempts at food or liquids"; 3 denotes "tube-dependent and alternative nutrition"; 4 describes "total oral diet of a single consistency"; 5 involves "total oral intake requiring special preparation or compensation"; 6 refers to "total oral intake with specific food limitations"; and 7 stands for "total oral intake with no restrictions."

### 2.4. Primary outcomes

The outcomes of this study are FOIS scores at two different time points: on the seventh day of hospitalization and after the completion of acute stroke treatment. Upon neurologists completing acute stroke therapy, patients fit for discharge may return home. At the same time,

those requiring ongoing rehabilitation due to complications may be transferred to a rehabilitation unit in the hospital or another convalescent hospital. Patients with no expected further improvement in post-stroke functional disabilities may be admitted to a specialized care facility.

### 2.5. Data collection

We collected baseline and outcome information from the medical charts, including age, sex, body mass index (BMI), National Institutes of Health Stroke Scale (NIHSS) score, time from onset to admission, pre-morbid modified Rankin Scale (mRS), subtypes of stroke, paralysis-side, lesion location, use of tissue plasminogen activator and thrombectomy, medical conditions, and laboratory values such as hemoglobin, and C-reactive protein. Data on pneumonia occurrence between Day 1 and 7 and patient destination pre- and post-acute phase were also included. All data were assessed within five days after admission. Laboratory values were assessed at admission.

### 2.6. Rehabilitation

Physiatrists tailored a comprehensive physical, occupational, and speech therapy regimen for each stroke patient based on their specific condition, thereby providing holistic rehabilitation. Each therapy session lasted between 20 and 40 minutes, adapted to the patient's unique needs. Patients with severe paralysis or dysphagia tended to receive rehabilitation more frequently, whereas speech therapy might not be administered if dysphagia was not present. In physical and occupational therapy, patients underwent range of motion exercises, muscle strengthening, activities of daily living training, gait training, and other functional mobility exercises. Speech therapy addressed deficits in voice, speech, and swallowing functions through vocalization exercises, articulation practice, language comprehension, and expression training, and feeding and swallowing rehabilitation; feeding and swallowing interventions comprised indirect techniques such as oral-motor exercises, multiple dry swallows, and coordination of breath-hold with swallowing, as well as direct techniques utilizing liquids or gels. Furthermore, mealtime observations were conducted to assess safe swallowing and adequate mastication. The rehabilitation team, including neurologists, physiatrists, nurses, and registered dietitians, collaborated to adjust the dietary form appropriate to the patient's condition.

### 2.7. Statistical analysis

Quantitative variables are presented as means (standard deviation) or medians [25th - 75th percentiles], based on the Shapiro-Wilk test for normality, while categorical variables are reported as frequencies (percentages). Between high and low PhA groups, an independent t-test and Mann-Whitney U test were applied to quantitative variables. Depending on expected frequencies, the chi-square or Fisher's exact test was used for categorical variables. A probability value of  $<0.05$  was considered significant.

Multivariate linear regression analysis of 2 models with FOIS scores on Day 7 after admission and after the completion of acute stroke treatment as the dependent variables were performed. Models 1 and 2 incorporated low PhA and confounding variables as independent variables. Models 3 and 4 included PhA along with the same confounding variables. These confounding variables include factors related to stroke-associated dysphagia, such as age, sex, NIHSS scores, premorbid mRS, type of stroke (ischemic vs intracranial hemorrhage), brainstem lesions, FOIS at the start of rehabilitation, and SMI [5,17,18]. Given that multivariate linear regression analysis requires a minimum of 15 cases per independent variable, this study required at least 135 cases to accommodate the nine variables in the model. Multicollinearity was assessed using the variance inflation factor, with a value below three generally indicating the absence of multicollinearity.

**Table 1**  
Comparison of patients with high and low phase angle.

	High PhA group N=64	Low PhA group N=76	P value
Age, year	70 [63–75]	79 [74–84]	<0.001
Male / women	40 / 24	45 / 31	0.731
BMI, kg/m <sup>2</sup>	25.1 [21.8 – 27.7]	21.8 [19.6–25]	<0.001
PhA, °	5.8 [5.4 – 6.2]	4.15 [3.5 – 4.6]	<0.001
SMI, kg/m2	7.11 ( 1.38 )	5.96 ( 1.22 )	<0.001
NIHSS, scores	3 [2–7]	4 [2–8]	0.219
Days from onset to admission	0 [0–1]	0 [0–1]	0.987
Premorbid mRS	0 [0]	0 [0–3]	<0.001
Predestination before onset			0.25
Home	64 ( 100 % )	73 ( 96.1 % )	
Care facility	0 ( 0 % )	3 ( 3.9 % )	
Stroke subtypes			0.134
Atherosclerosis	21 ( 32.8 % )	28 ( 36.8 % )	
Cardioembolic	5 ( 7.8 % )	14 ( 18.4 % )	
Small vessel occlusion	9 ( 14.1 % )	14 ( 18.4 % )	
Intracranial hemorrhage	10 ( 15.6 % )	6 ( 18.4 % )	
Others	19 ( 29.7 % )	14 ( 18.4 % )	
Location of stroke lesion			
Supratentorial	53 ( 82.8 % )	65 ( 85.5 % )	0.816
Brainstem	7 ( 10.9 % )	6 ( 7.9 % )	0.571
Cerebellar	6 ( 9.4 % )	3 ( 3.9 % )	0.301
Paralysis			0.839
Right	21 ( 32.8 % )	28 ( 36.8 % )	
Left	30 ( 46.9 % )	32 ( 42.1 % )	
No	13 ( 20.3 % )	16 ( 21.1 % )	
Use of tissue plasminogen activator	5 ( 7.8 % )	6 ( 7.9 % )	1.0
Thrombectomy	2 ( 3.1 % )	6 ( 7.9 % )	0.29
Medical condition			
Hypertension	40 ( 62.5 % )	54 ( 71.1 % )	0.367
Diabetes mellitus	9 ( 14.1 % )	20 ( 26.3 % )	0.095
Dyslipidemia	23 ( 35.9 % )	29 ( 38.2 % )	0.861
Atrial fibrillation	3 ( 4.7 % )	15 ( 19.7 % )	0.010
Previous stroke	17 ( 26.6 % )	24 ( 31.6 % )	0.578
Hemoglobin, g/dL	14 ( 1.8 )	12.9 ( 1.9 )	<0.001
C-reactive protein, mg/dL	0.23 [0.07 – 0.49]	0.16 [0.09 – 0.76]	0.706
Aspiration pneumonia onset until Day 7	4 ( 6.3 % )	13 ( 17.1 % )	0.07
Physical therapy days until Day 7	4 [3,4]	4 [3,4]	0.401
Occupational therapy days until Day 7	4 [3,4]	4 [3,4]	0.691
Speech therapy days until Day 7	3 [0–4]	3 [2–4]	0.678
Days during the acute phase	13 [10–20]	15 [10–21]	0.174
Destination after the completion of acute treatment			0.030
Home	25 ( 39.1 % )	16 ( 21.1 % )	
Convalescent hospital	21 ( 32.8 % )	35 ( 46.1 % )	
Rehabilitation units	18 ( 28.1 % )	21 ( 27.6 % )	
Care facility	0 ( 0 % )	4 ( 5.3 % )	

Divided high and low PhA values based on the cutoff values of <5.28° in men and <4.62 in women.

PhA, phase angle; BMI, body mass index, NIHSS, National Institutes of Health Stroke Scale; mRS, modified Rankin Scale; SMI, skeletal muscle mass index.

2.8. Ethics

This study was conducted according to the Declaration of Helsinki and approved by the Ethics Committee of the University of Occupational and Environmental Health [CR23–110]. Due to the study’s retrospective observational nature, written informed consent was not obtained. However, all patients retained the right to withdraw from the study at any point.

3. Results

Of 179 consecutive acute stroke patients who were admitted within seven days after onset and required rehabilitation, we excluded patients

**Table 2**  
Swallowing results at the start of rehabilitation, on Day 7 after admission, and after acute stroke treatment.

	High PhA group N=64	Low PhA group N=76	P value
FOIS			
At rehabilitation started	6 [2–7]	5 [2–7]	0.393
1	16	16	
2	2	4	
3	0	0	
4	3	7	
5	10	18	
6	5	7	
7	28	24	
On Day 7	7 [5–7]	5[2–6]	0.001
1	6	13	
2	0	7	
3	0	1	
4	2	2	
5	18	25	
6	6	9	
7	32	19	
After the completion of acute stroke treatment	7 [5–7]	5 [4–7]	0.002
1	1	8	
2	2	6	
3	1	3	
4	2	3	
5	19	25	
6	7	9	
7	32	22	

Divided high and low PhA values based on the cutoff values of <5.28° in men and <4.62 in women.

FOIS; functional oral intake scale; PhA, phase angle.

as follows: 6 patients discharged within seven days of admission, 4 with missing data, 2 patients who underwent craniotomy, 2 patients with lateral medullary syndrome, 7 patients with bilateral hemiplegia, 1 patient with neuromuscular disease, 8 patients with hemodialysis, 5 patients with a pacemaker, 1 patient who died during hospitalization, 2 patients who transferred to another department because of complications other than stroke, and 1 patient with severe dysphagia before stroke onset. Therefore, 140 acute stroke patients (median age 74 [69–81], 85 men and 55 women, and median days between onset and admission 0 [0,1]) were analyzed in this study.

Table 1 compares 64 patients with high PhA and 76 with low PhA. Those with low PhA were older, had lower BMI, greater decline in SMI, lower premorbid mRS scores, and more comorbidities with atrial fibrillation (p-values <0.001 and 0.01, respectively). Regarding discharge destinations, a higher percentage of patients in the low PhA group were transferred to convalescent hospitals or care facilities than those in the high PhA group (p=0.03).

Table 2 presents the FOIS scores, indicating swallowing outcomes. At the start of rehabilitation, the median FOIS scores were 5 [2–7] for patients with low PhA and 6 [2–7] for those with high PhA, showing no significant difference (p=0.393). However, significant differences emerged by Day 7 post-admission (median FOIS scores: 7 [5–7] vs 5 [2–6], p=0.001) and after the completion of acute stroke treatment (median FOIS scores: 7 [5–7] vs 5 [4–6], p=0.002) between patients with high and low PhA.

Tables 3 and 4 display results from multivariate linear regression analyses of FOIS scores on Day 7 after admission and after the completion of acute stroke treatment. The studies revealed that low PhA was independently associated with lower FOIS scores both on Day 7 after admission ( $\beta = -0.143$ ,  $B = -0.59$ ; 95 % CI:  $-1.141$  to  $-0.04$ ;  $p = 0.036$ ) and after the completion of acute stroke treatment ( $\beta = -0.513$ ,  $B = -0.55$ ; 95 % CI:  $-1.027$  to  $-0.074$ ;  $p = 0.024$ ). These models were adjusted for age, sex, NIHSS points, premorbid mRS, type of stroke (ischemic or intracranial hemorrhage), brainstem lesion, initial FOIS scores, and SMI. However, PhA was not significantly associated with

**Table 3**  
Multivariate linear regression analysis with functional oral intake scale on Day 7 after admission and after the completion of acute stroke treatment with low phase angle and confounding variables.

Variables	Model 1			Model 2		
	Outcome	FOIS on Day 7 after admission		Outcome	FOIS after the completion of acute stroke treatment	
	$\beta$	B ( 95 %CI )	<i>P</i> value	$\beta$	B ( 95 %CI )	<i>P</i> value
Age	-0.106	-0.02 ( -0.044, 0.012 )	0.110	-0.06	-0.01 ( -0.031, 0.012 )	0.366
Men	-0.07	-0.279 ( -0.845, 0.288 )	0.332	-0.025	-0.09 ( -0.581, 0.4 )	0.715
NIHSS	-0.35	-0.107 ( -0.15, -0.063 )	<0.001	-0.322	-0.086 ( -0.123, -0.048 )	<0.001
Premorbid mRS	-0.045	-0.058 ( -0.242, 0.126 )	0.535	-0.119	-0.158 ( -0.318, 0.001 )	0.051
Ischemic stroke	-0.023	-0.097 ( -0.644, 0.451 )	0.727	-0.053	-0.223 ( -0.696, 0.251 )	0.354
Brainstem lesion	-0.03	-0.225 ( -1.009, 0.558 )	0.571	-0.012	-0.076 ( -0.754, 0.602 )	0.825
FOIS at rehabilitation started	0.441	0.385 ( 0.258, 0.511 )	<0.001	0.47	0.356 ( 0.247, 0.466 )	<0.001
SMI	0.088	0.129 ( -0.099, 0.357 )	0.264	0.048	0.062 ( -0.136, 0.259 )	0.538
Low PhA	-0.143	-0.59 ( -1.141, -0.04 )	0.036	-0.153	-0.55 ( -1.027, -0.074 )	0.024

Model 1, adjusted R<sup>2</sup>=0.591, p<0.001  
Model 2, adjusted R<sup>2</sup>=0.599, p<0.001  
Low PhA was the cutoff value of <5.28 in men and <4.62 in women.  
NIHSS, National Institutes of Health Stroke Scale; mRS, modified Rankin Scale; FOIS, functional oral intake scale; SMI, skeletal muscle mass index; PhA, phase angle.

**Table 4**  
Multivariate linear regression analysis with functional oral intake scale on Day 7 after admission and after the completion of acute stroke treatment with phase angle and confounding variables.

Variables	Model 3			Model 4		
	Outcome	FOIS on Day 7 after admission		Outcome	FOIS after the completion of acute stroke treatment	
	$\beta$	B ( 95 %CI )	<i>P</i> value	$\beta$	B ( 95 %CI )	<i>P</i> value
Age	-0.075	-0.024 ( -0.049, 0.001 )	0.057	-0.130	-0.012 ( -0.033, 0.009 )	0.267
Men	-0.054	-0.4 ( -0.959, 0.16 )	0.16	-0.095	-0.199 ( -0.682, 0.284 )	0.416
NIHSS	-0.311	-0.103 ( -0.147, -0.059 )	<0.001	-0.338	-0.083 ( -0.121, -0.044 )	<0.001
Premorbid mRS	-0.115	-0.066 ( -0.259, 0.127 )	0.502	-0.043	-0.153 ( -0.32, 0.014 )	0.071
Ischemic stroke	-0.064	-0.149 ( -0.7, 0.402 )	0.593	-0.031	-0.267 ( -0.743, 0.208 )	0.268
Brainstem lesion	-0.010	-0.211 ( -1.0, 0.582 )	0.6	-0.030	-0.06 ( -0.745, 0.625 )	0.863
FOIS at rehabilitation started	0.481	0.392 ( 0.264, 0.52 )	<0.001	0.452	0.364 ( 0.254, 0.475 )	<0.001
SMI	0.045	0.143 ( -0.097, 0.383 )	0.242	0.010	0.057 ( -0.15, 0.264 )	0.586
PhA	0.126	0.144 ( -0.113, 0.401 )	0.269	0.087	0.183 ( -0.039, 0.405 )	0.105

Model 3, adjusted R<sup>2</sup>=0.591, p<0.001  
Model 4, adjusted R<sup>2</sup>=0.599, p<0.001  
NIHSS, National Institutes of Health Stroke Scale; mRS, modified Rankin Scale; FOIS, functional oral intake scale; SMI, skeletal muscle mass index; PhA, phase angle.

FOIS scores either on Day 7 after admission ( $\beta = -0.126$ ,  $B = -0.144$ ; 95 % CI:  $-0.113-0.401$ ;  $p = 0.269$ ) or after the completion of acute stroke treatment ( $\beta = -0.087$ ,  $B = -0.55$ ; 95 % CI:  $-0.039-0.405$ ;  $p = 0.105$ ).

4. Discussion

We have shown that low PhA was negatively associated with FOIS on Day 7 of hospitalization and after acute stroke treatment. As far as we know, this is the first study to demonstrate a negative relationship between PhA and swallowing function in patients with acute stroke. According to the study by Fukuma et al., sarcopenia has been associated with the onset of dysphagia in patients with acute stroke. It is essential to diagnose sarcopenia by measuring grip strength on the non-paralyzed side and SMI [7,12,19]. However, consciousness disorders after a stroke may challenge grip strength measurement. Muscle strength diminishes due to muscle wasting with rest [20,21], and intravenous therapy-related lower limb edema can make skeletal muscle mass measurement inaccurate. Sato et al. [12] propose a cutoff value of PhA for identifying sarcopenia in patients with acute stroke as 5.28 for men and 4.62 for women, which may be more clinically useful than diagnosing sarcopenia alone for identifying patients at high risk of decreased swallowing function. PhA measurement, which is unaffected by consciousness disorders, is non-invasive and quick, making it a potential alternative to grip strength and SMI for sarcopenia diagnosis. PhA reflects cell health, with low values indicating reduced physiological efficiency at the cellular level

[8,9]. This reduction could affect the functionality of skeletal muscles involved in swallowing and their coordination post-stroke. Our study found that patients with low PhA had decreased skeletal muscle mass. Since low skeletal muscle mass indicates nutritional status [22,23], the impaired swallowing function in patients with low PhA suggests malnutrition may impede the recovery of this function. More patients had low PhA than reported by Sato et al. [12]. Unlike our patient selection criteria, Sato et al. included patients with mild illness within seven days of admission and patients with severe disturbance of consciousness. This difference suggests that many of the patients in our study had low PhA. In our multivariate linear regression analysis, low PhA was independently associated with FOIS scores on Day 7 after admission and after the completion of acute stroke treatment, however, PhA was not associated. This may indicate that some conditions may be more prone to the emergence of health risks reflected in the PhA at a certain point in post-stroke swallowing function. Further studies are needed to determine whether the PhA cutoff values adopted in this study are appropriate for identifying health risk emergence in stroke treatment. While the beta coefficient for PhA is relatively tiny ( $\beta=0.143$ ), its statistical significance in the regression model indicates a consistent influence on swallowing function that is not due to chance, suggesting a meaningful impact despite its modest size. Moreover, previous research has demonstrated that low PhA, assessed with the same cutoff used in our study, is associated with a higher likelihood of home discharge among elderly stroke patients [24]. This finding highlights the broader clinical significance of phase angle, emphasizing its value in predicting



patient outcomes and justifying its inclusion in studies assessing recovery and rehabilitation in this population.

This study has several limitations. It is a single-center study, which may limit the generalizability of the findings. The causal relationship between PhA value and swallowing function cannot be established because of its observational nature. Details of swallowing function before hospitalization were not assessed. The upper limit of recovery of swallowing function in patients with high PhA may have been lower than for patients without low PhA. The hospitalization was within seven days of onset, leading to potential variability in PhA measurement. Future studies should be conducted using a protocol that standardizes the time from onset to PhA measurement. In conclusion, low PhA is negatively associated with swallowing function in patients with acute stroke. Nutritional and physical interventions improving PhA may lead to a reduction of the risk associated with stroke sequelae.

## Funding

Health Labour Science Research Grants of the Ministry of Health Labour and Welfare supported this study (Grant No. 230301-1).

## CRediT authorship contribution statement

**Satoru Saeki:** Funding acquisition, Investigation, Supervision. **Toshiyuki Moriyama:** Conceptualization, Data curation, Formal analysis, Investigation, Software, Writing – original draft, Writing – review & editing. **Yasuyuki Matsushima:** Investigation. **Mitsuhiro Ochi:** Investigation. **Hideaki Itoh:** Investigation. **Akiko Hachisuka:** Investigation. **Ryoko Hori:** Conceptualization, Investigation. **Mizuki Tokunaga:** Conceptualization, Investigation, Project administration.

## Declaration of Competing Interest

The funding body was not involved in the design and conduct of the study, including the decision to submit the manuscript for publication. The authors declare no conflict of interest.

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## Original article

## Association between phase angle and sarcopenia in patients with connective tissue diseases

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## ARTICLE INFO

## Article history:

Received 1 July 2024

Accepted 21 October 2024

## Keywords:

Sarcopenia

Phase angle

Connective tissue diseases

Bioimpedance analysis

## SUMMARY

**Background and aims:** Early detection and management of sarcopenia in patients with connective tissue diseases (CTDs) are essential. However, the relationship between the phase angle and sarcopenia in patients with CTDs is unknown. This study investigated the association between the phase angle and sarcopenia in patients with (CTDs) and determined the optimal phase angle cutoff values for the early detection of sarcopenia.

**Methods:** A retrospective cross-sectional study was conducted in 279 hospitalized patients with CTDs undergoing rehabilitation (median age 73.3 years; 80 men and 199 women). Bioimpedance analysis was used to measure the phase angle, and sarcopenia was assessed according to the Asian Working Group for Sarcopenia criteria.

**Results:** Sarcopenia was identified in 134 patients (36 men and 98 women). Patients with sarcopenia had a significantly smaller phase angle than those without sarcopenia. Multivariate analysis revealed that phase angle was significantly associated with sarcopenia after adjusting for confounding factors in each sex. The optimal phase angle cutoff value for identifying sarcopenia was 4.6° for men and 4.3° for women, with area under the curve values of 0.795 and 0.754, respectively.

**Conclusion:** Phase angle is a valuable marker for identifying sarcopenia in patients with CTDs. The established phase angle cutoff values of 4.6° in men and 4.3° in women can facilitate the early detection and management of sarcopenia.

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## 1. Introduction

Connective tissue diseases (CTDs) are characterized by systemic inflammation and tissue destruction through autoimmune mechanisms, seriously affecting overall health [1,2]. CTDs include a diverse group of diseases, such as rheumatoid arthritis (RA), systemic sclerosis (SSc), polymyositis/dermatomyositis (PM/DM), and systemic lupus erythematosus (SLE), among others. These diseases can cause chronic systemic inflammation, joint pain, and

deformities. Steroid treatment reduces muscle strength and mass and increases the risk of sarcopenia [3,4].

Sarcopenia is a skeletal muscle disease characterized by progressive and generalized loss of muscle mass and strength, resulting in significant health risks such as falls and increased mortality [5,6]. Therefore, early detection and intervention of sarcopenia in patients with CTDs are essential.

The phase angle is a continuous measure calculated using bioimpedance analysis (BIA), reflecting cell membranes' stability and

**Abbreviations:** AAV, anti-neutrophil cytoplasmic antibody-associated vasculitis; AUC, area under the curve; BIA, bioimpedance analysis; BMI, body mass index; CTDs, connective tissue diseases; CRP, C-reactive protein; DEXA, Dual X-ray Absorptiometry; ECW/TBW, extracellular water-to-total body water; GCA, giant cell arteritis; HGS, handgrip strength; MCTD, mixed connective tissue disease; PM/DM, polymyositis/dermatomyositis; RA, rheumatoid arthritis; ROC, receiver operating characteristics; SLE, systemic lupus erythematosus; SMI, skeletal muscle index; SS, Sjögren's syndrome; SSc, systemic sclerosis; VIF, variance inflation factor.

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<https://doi.org/10.1016/j.clnesp.2024.10.159>

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water balance in the body [7,8]. It assesses health risks non-invasively and at a low medical cost. A low phase angle has been reported to be associated with skeletal muscle status, such as decreased muscle strength and mass, as well as nutritional status [9–12]. Phase angle is negatively associated with sarcopenia in patients with stroke, heart disease, and cancer [13–17]. While the impact of sarcopenia on health is based on its presence or absence, a lower phase angle has been reported to be associated with higher all-cause mortality [18–20], providing a continuous measure of impact on health. Phase angle may be a better indicator of health risk than sarcopenia. However, the relationship between the phase angle and sarcopenia in patients with CTDs is unknown.

We investigated the association between the phase angle and sarcopenia in patients with CTDs and calculated cutoff values for the early detection of sarcopenia.

## 2. Methods

### 2.1. Study settings and patients

This retrospective cross-sectional study included admitted patients with CTDs who underwent rehabilitation between February 2022 and March 2024. The study included patients diagnosed with CTDs. The diagnosis of CTDs was based on the respective classification criteria [21–24] or requirements defined by the Japan Research Committee on Intractable Diseases of the Ministry of Health, Labor and Welfare [25]. Rehabilitation was performed to ameliorate the decline in physical activity during inpatient treatment. Patients with unhealed fractures on the right side, acute stroke, and missing data were excluded. This study was approved by the Ethics Committee of the University of Occupational and Environmental Health [CR23-110] and was conducted in accordance with the Declaration of Helsinki. Due to the retrospective observational design of the study, written informed consent was not required. All the patients had the option to withdraw from the study at any time.

### 2.2. Phase angle and sarcopenia assessment

At the start of rehabilitation, we used a BIA device (InBody S10, InBody Japan, Tokyo, Japan) to assess patients lying after resting for 10 min and fasting for at least 2 h. Phase angle was calculated from the impedance values of the right side at 50 kHz using the equation  $\arctangent(X/R) \times (180/\pi)$ , where X represents reactance and R represents resistance. Extracellular water-to-total body water ratio (ECW/TBW) and appendicular skeletal muscle mass were measured. The skeletal muscle index (SMI) was the ratio between appendicular skeletal muscle mass and height. Handgrip strength (HGS) was measured twice for each hand using a handgrip dynamometer (Grip-D, Takei Scientific Instruments, Niigata, Japan), with the highest value used for analysis. Sarcopenia was defined as low HGS and SMI using cutoff values of <28 kg and <7.0 kg/m<sup>2</sup> for men and <18 kg and <5.7 kg/m<sup>2</sup> for women, as per the Asian Working Group for Sarcopenia 2019 criteria [4].

### 2.3. Medical record data

Medical charts collected data on body mass index (BMI), comorbidities, use of disease-modifying antirheumatic drugs, oral prednisolone dose, and days from admission to rehabilitation. The CTD types were categorized as RA, SSc, PM/DM, anti-neutrophil cytoplasmic antibody-associated vasculitis (AAV), Sjögren's syndrome (SS), SLE, mixed connective tissue disease (MCTD), giant cell arteritis (GCA), and others. C-reactive protein (CRP) and hemoglobin levels were assessed upon admission.

### 2.4. Statistical analysis

All statistical analyses were conducted using the “EZ” software for Windows [26]. Statistical significance was set at  $p < 0.05$ . Categorical variables are presented as numbers and percentages. Ordinal variables were presented as a median and interquartile range [IQR, 25th–75th percentiles]. Continuous variables were presented as mean and standard deviation or median and [IQR], depending on the data distribution normality, which was assessed using the Shapiro–Wilk test. When comparing patients with and without sarcopenia, categorical variables were analyzed using chi-square and Fisher's exact tests. Quantitative variables, including ordinal and continuous variables, were analyzed using the t-test or Mann–Whitney U test after normality assessment using the Shapiro–Wilk test. Pearson and Spearman rank correlation analyses assessed the correlation coefficients between the phase angle and sarcopenia-related factors, including age, BMI, HGS, SMI, and hemoglobin level for each sex. Multivariate linear regression analysis of the phase angle was performed for each sex. Models 1 and 2 included age, BMI, RA incidence, ECW/TBW, hemoglobin level, and sarcopenia. Multicollinearity was evaluated using the variance inflation factor (VIF), with a VIF range of 1–3 indicating no multicollinearity. The optimal cutoff values of the phase angle for distinguishing sarcopenia were determined using receiver operating characteristic (ROC) curves for both sexes based on the Youden index.

## 3. Results

Of the 283 hospitalized patients with CTDs, one with an unhealed fracture on the right side, one with acute stroke and two with missing data were excluded. The final analysis included 279 patients (median age 73.3 years; 80 men and 199 women; median phase angle, 4.3°).

Table 1 shows patient characteristics and comparisons between patients with and without sarcopenia. The distribution of CTD types was as follows: RA was the most common ( $N = 112$ ), followed by SSc ( $N = 66$ ), PM/DM ( $N = 50$ ), AAV ( $N = 35$ ), SS ( $N = 23$ ), SLE ( $N = 21$ ), MCTD ( $N = 15$ ), GCA ( $N = 4$ ), and others ( $N = 5$ ). Some patients had multiple CTDs. The “others” category included one patient with adult Still's disease, one with polyarteritis nodosa, Takayasu arteritis, and two with Behçet's disease. Sarcopenia was observed in 134 (48 %) patients, including 36 men (45 %) and 98 women (49.2 %). Patients with sarcopenia were older ( $p < 0.001$ ), had a lower BMI ( $p < 0.001$ ), were more likely to have RA ( $p < 0.001$ ) and SSc ( $p = 0.007$ ), were more likely to have osteoporosis ( $p < 0.001$ ), had higher ECW/TBW ( $p < 0.001$ ) and CRP ( $p = 0.019$ ) levels, and had lower hemoglobin levels ( $p = 0.001$ ). The phase angle was lower in patients with sarcopenia than those without ( $p < 0.001$ ).

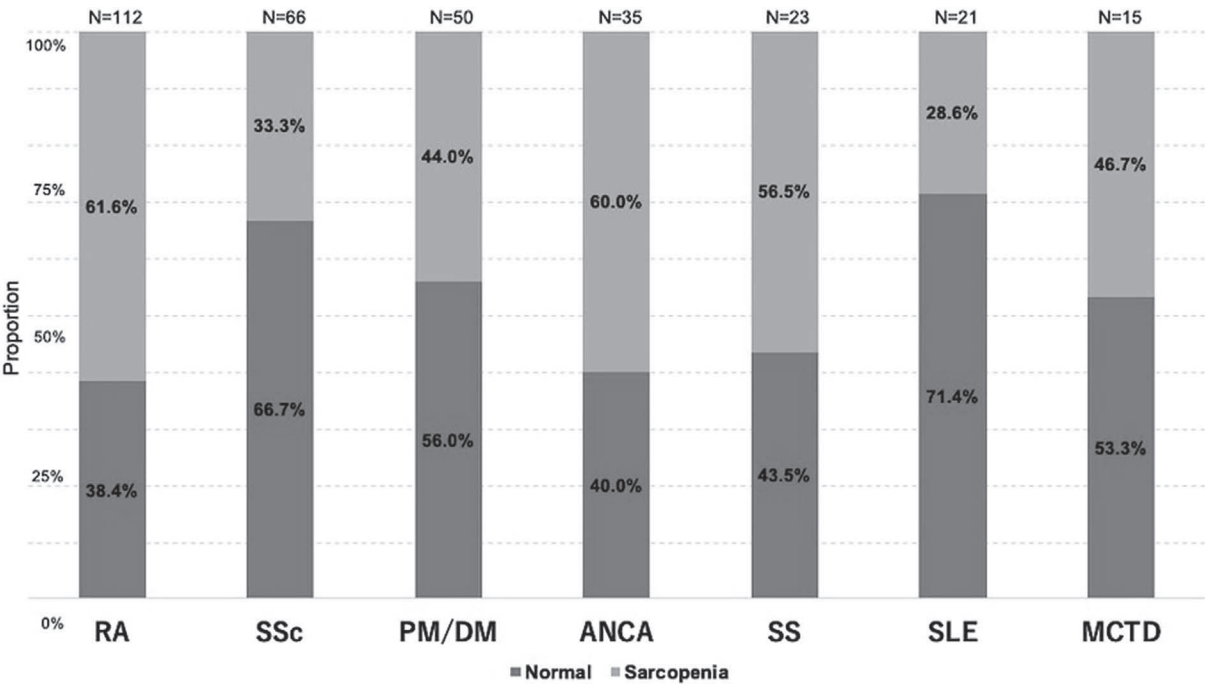
As shown in Fig. 1, the prevalence of sarcopenia was 51.5 % and 33.3 % in patients with RA and SSc, respectively. The combined prevalence of sarcopenia was 44.0 % for PM/DM, 60.0 % for AAV, 37.5 % for SS, 28.6 % for SLE, and 46.7 % for MCTD.

Table 2 presents the results of the Pearson correlation and Spearman rank correlation analyses between the phase angle and sarcopenia-related factors in both sexes. In men, the phase angle correlated with age ( $r = -0.301$ ,  $p = 0.007$ ), BMI ( $r = 0.384$ ,  $p < 0.001$ ), HGS ( $r = 0.559$ ,  $p < 0.001$ ), and hemoglobin level ( $r = 0.582$ ,  $p < 0.001$ ). In women, the phase angle correlated with age ( $\rho = -0.517$ ,  $p < 0.001$ ), BMI ( $\rho = 0.253$ ,  $p < 0.001$ ), HGS ( $\rho = 0.532$ ,  $p < 0.001$ ), SMI ( $\rho = 0.38$ ,  $p < 0.001$ ), and hemoglobin ( $\rho = 0.432$ ,  $p < 0.001$ ). Table 3 presents the multivariate linear regression analysis results with the phase angle as the dependent variable, analyzed separately for men and women.

**Table 1**  
Comparing patients with and without sarcopenia.

	Overall (N = 279)	Sarcopenia (+) (N = 134)	Sarcopenia (−) (N = 145)	P
Age, years	73.3 [66.3–79.1]	75.4 [68.9–80.3]	70.5 [62.7–75.8]	<0.001
Men, n (%)	80 (28.7 %)	36 (26.9 %)	44 (30.3 %)	0.596
BMI, kg/m <sup>2</sup>	21.6 [19.5–24.1]	20.4 (2.6)	23.4 (3.7)	<0.001
CTD types, n (%)				
RA	112 (40.1 %)	69 (51.5 %)	43 (29.7 %)	<0.001
SSc	66 (23.7 %)	22 (16.4 %)	44 (30.3 %)	0.007
PM/DM	50 (17.9 %)	22 (16.4 %)	28 (19.3 %)	0.537
AAV	35 (12.5 %)	21 (15.7 %)	14 (9.7 %)	0.15
SS	23 (8.2 %)	13 (9.7 %)	10 (6.9 %)	0.514
SLE	21 (7.5 %)	6 (4.5 %)	15 (10.3 %)	0.072
MCTD	15 (5.4 %)	7 (5.2 %)	8 (5.5 %)	1
GCA	4 (1.4 %)	2 (1.5 %)	2 (1.4 %)	1
Others	5 (1.8 %)	2 (1.5 %)	3 (2.1 %)	1
Comorbidities, n (%)				
Hypertension	123 (44.1 %)	64 (47.8 %)	59 (40.7 %)	0.277
Diabetes mellitus	61 (21.9 %)	30 (22.4 %)	21 (21.4 %)	0.885
Interstitial lung disease	164 (58.8 %)	79 (59 %)	85 (58.6 %)	1
Osteoporosis	124 (44.4 %)	74 (55.2 %)	50 (34.5 %)	<0.001
Dementia	7 (2.5 %)	5 (3.8 %)	2 (1.4 %)	0.265
ECW/TBW	0.4 [0.39–0.41]	0.4 [0.4–0.41]	0.39 [0.39–0.4]	<0.001
HGS, kg	16.3 [11–20.9]	13.6 [8.6–16.8]	19.6 [15.4–24.2]	<0.001
SMI, kg/m <sup>2</sup>	5.7 [5.1–6.4]	5.2 [4.7–5.6]	6.4 [5.8–7.3]	<0.001
Phase angle, °	4.3 (1.08)	3.9 [3.4–4.5]	4.7 [4–5.4]	<0.001
CRP, mg/dL	0.51 [0.13–3.47]	1.12 [0.15–4.73]	0.4 [0.11–1.71]	0.019
Hemoglobin, g/dL	11.7 [10.2–13]	11.3 [9.5–12.5]	12 [10.7–13.2]	0.001
Days from admission to rehabilitation start day	1 [1–3]	1 [1–3]	1 [1–3]	0.417
Daily use of DMARDs, n (%)	60 (21.5 %)	31 (23.1 %)	29 (20 %)	0.561
Oral prednisolone dose, mg/day	0 [0–2]	0 [0–3]	0 [0–1]	0.313
Preadmission, n (%)				0.18
Home	249 (89.2 %)	116 (86.6 %)	133 (91.7 %)	
Another hospital	30 (10.8 %)	18 (13.4 %)	12 (8.3 %)	

BMI, body mass index; CTDs, connective tissue diseases; ECW/TBW, extracellular water-to-total body water ratio; RA, rheumatoid arthritis; SSc, systemic sclerosis, PM, polymyositis; DM, dermatomyositis; AAV, anti-neutrophil cytoplasmic antibody-associated vasculitis; SS, Sjögren's syndrome; SLE, systemic lupus erythematosus; MCTD, mixed connective tissue disease; GCA, giant cell arteritis; HGS, handgrip strength; SMI, Skeletal muscle index; CRP, C-reactive protein; DMARDs, disease-modifying anti-rheumatic drugs.



**Fig. 1.** The prevalence of sarcopenia in each connective tissue disease.

**Table 2**  
Results of the Pearson correlation and Spearman rank correlation analysis between phase angle and sarcopenia-related factors in both sexes.

Variable	Men			Women		
	Overall (N = 80)	r	P value	Overall (N = 199)	rho	P value
Age	72.8 (9.3)	−0.301	0.007	72.5 [65.3–78.9]	−0.517	<0.001
BMI	22.5 (3.1)	0.384	<0.001	21.3 [19.3–23.8]	0.253	<0.001
HGS	22.8 (8.6)	0.559	<0.001	15 [9.3–18.2]	0.532	<0.001
SMI	6.8 (1.2)	0.097	0.394	5.4 [4.9–6]	0.38	<0.001
Hemoglobin	11.8 (2.2)	0.582	<0.001	11.7 [10.2–12.6]	0.432	<0.001
Phase angle	4.63 (1.14)			4.14 (1.02)		

BMI, body mass index; HGS, handgrip strength; SMI, skeletal muscle index.  
Pearson correlation coefficients for all variables in men. Spearman rank correlation for all variables in women.

**Table 3**  
Multivariate linear regression analysis with phase angle in both sexes.

Variable	Model 1	Men			Model 2	Women		
	β	B	95 % CI	P	β	B	95 % CI	P
Age	0.077	0.007	(−0.005, 0.019)	0.229	−0.048	−0.004	(−0.011, 0.002)	0.157
BMI	0.13	0.039	(0.001, 0.079)	0.046	0.097	0.029	(0.011, 0.048)	0.002
RA	0.009	0.019	(−0.182, 0.22)	0.85	0.03	0.065	(−0.065, 0.196)	0.325
ECW/TBW	−0.887	−66.259	(−74.15, −58.36)	<0.001	−0.816	−60.97	(−66.4, −55.54)	<0.001
Hemoglobin	0.001	0	(−0.054, 0.055)	0.996	−0.001	0	(−0.0011, 0.01)	0.97
Sarcopenia	−0.126	−0.272	(−0.507, −0.037)	0.024	−0.11	−0.238	(−0.381, −0.094)	0.013

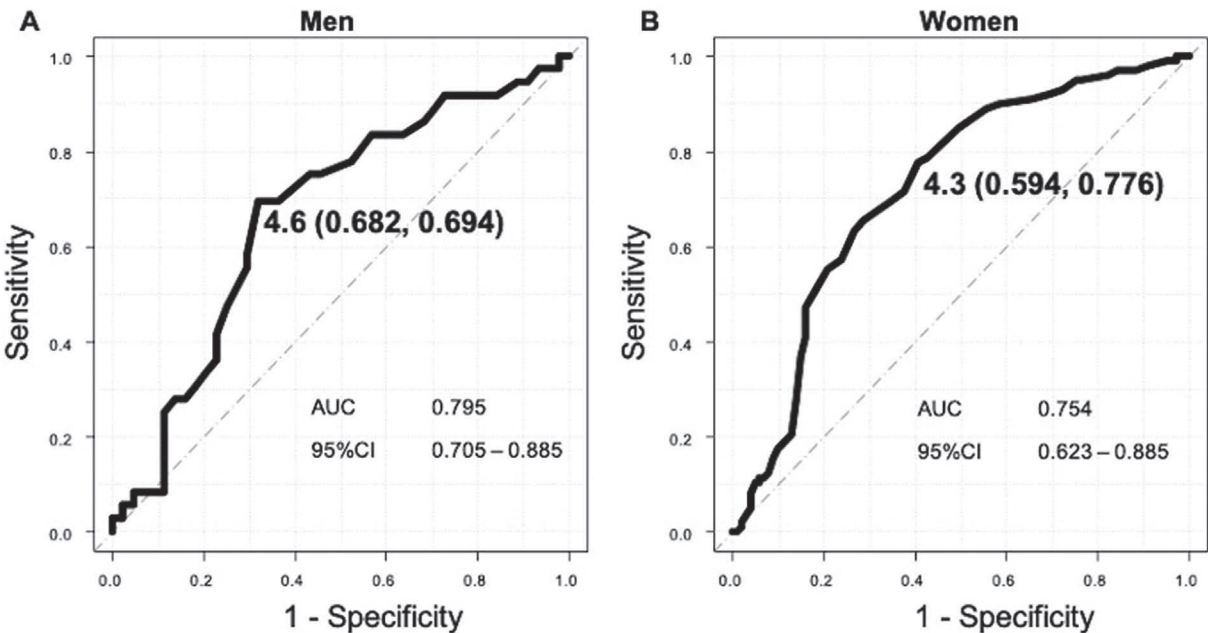
BMI, body mass index; RA, rheumatoid arthritis; ECW/TBW, extracellular water-to-total body water; CI, confidence interval.  
Adjusted R<sup>2</sup>: Model 1, 0.867; Model 2, 0.823.

Model 1 revealed that sarcopenia was negatively associated with phase angle ( $\beta = -0.126$ ,  $B = -0.272$ , 95 % confidence interval  $-0.507$  to  $-0.037$ ,  $p = 0.024$ ), adjusted for age, BMI, RA incidence, ECW/TBW, and hemoglobin level in men. Model 2 revealed that sarcopenia was negatively associated with phase angle ( $\beta = -0.11$ ,  $B = -0.238$ , 95 % confidence interval  $-0.381$  to  $-0.094$ ,  $p = 0.013$ ) adjusted for age, BMI, RA incidence, ECW/TBW, and hemoglobin level in women. As shown in Fig. 2, a ROC curve analysis was conducted to determine the optimal phase angle cutoff values for discriminating sarcopenia in patients with CTDs. For men, the optimal phase angle cutoff value for identifying

sarcopenia was  $4.6^\circ$ , with a sensitivity of 0.694, specificity of 0.682, and area under the curve (AUC) of 0.795. In women, the optimal phase angle cutoff value was  $4.3^\circ$ , with a sensitivity of 0.776, specificity of 0.594, and AUC of 0.754.

4. Discussion

We showed that the phase angle was negatively associated with sarcopenia in hospitalized patients with CTDs and that the optimal cutoff values of the phase angle for discriminating sarcopenia were  $4.6^\circ$  in men and  $4.3^\circ$  in women. To the best of our knowledge, this is



**Fig. 2.** ROC curves to discriminate the optimal phase angle cutoff valued for identifying sarcopenia in men (A) and women (B).



the first study to demonstrate the relationship between the phase angle and sarcopenia and the usefulness of the phase angle in assessing health risks in patients with CTDs in clinical practice.

The phase angle cutoff values for sarcopenia in patients with stroke, cancer, heart disease, and elderly individuals are 4–5° [13–17]. These values are higher in males than in females. In contrast, the phase angle in healthy individuals has been reported to be 6–7° [27,28]. Matsumoto et al. [29] reported that in patients with RA, the phase angle cutoff value as a predictor of falls was 5.26° in men and 4.06° in women. The cutoff values for sarcopenia in this study were 4.6° in men and 4.3° in women, suggesting that sarcopenia is associated with an increased health risk in patients with CTDs, as in other diseases.

International criteria for diagnosing sarcopenia recommend assessing skeletal muscle mass using BIA or Dual X-ray Absorptiometry (DEXA). However, the BIA method can overestimate fluid overload due to edema, interpreting it as increased skeletal muscle mass [30]. Additionally, DEXA involves low radiation exposure and high maintenance costs; patients must also be moved to a dedicated facility and may require assistance for examination. In contrast, phase angle measurement using the BIA method reflects the current cell membrane stability and water balance, directly measuring the overall whole-body health status. It is noninvasive, portable, inexpensive to maintain, and can be performed at the bedside by a single evaluator, making it easy to apply in clinical settings.

The prevalence of sarcopenia in this study was 48 %, with 45 % in men and 49 % in women, showing little difference between sexes. Additionally, the prevalence of sarcopenia was 61.6 % and 33.3 % in patients with RA and SSc, respectively. In previous reports, the prevalence of sarcopenia was 37.1 % in patients with RA [31] and 22.8 % in patients with SSc [32]; the prevalence in the present study was higher. Furthermore, the prevalence of sarcopenia exceeded 40 % in patients with PM/DM, ANCA, SS, and MCTD. The higher prevalence of sarcopenia in the present study may be because all patients were hospitalized and required treatment. Previous reports [31,32] excluded patients who had difficulty walking.

The  $\beta$  coefficient for ECW/TBW was significantly more prominent compared to other variables because phase angle reflects the body's water balance, derived from the BIA method, including extracellular and intracellular water compartments. However, the strong relationship between ECW/TBW and phase angle does not obscure the association between sarcopenia and phase angle. The negative correlation between sarcopenia and the phase angle remained significant even after adjusting for ECW/TBW. This indicates that, while the phase angle is influenced by fluid balance, it still independently correlates with muscle mass and strength, which are critical components of sarcopenia. Therefore, the phase angle can serve as a reliable marker of sarcopenia, reflecting both water balance and muscle health.

In this study, the phase angle was positively correlated with the cutoff value for identifying sarcopenia and its associated factors: age, BMI, HGS, SMI, and hemoglobin level. This suggests that phase angle values can detect sarcopenia early and aid in developing individualized treatment plans, as they reflect the detailed aspects of a patient's health status.

The following considerations should be made regarding the phase angle. This value may vary owing to the use of different measuring instruments [33]. It is sensitive to changes in the body water content and may vary before and after urination. This is a value for the right hemibody and mainly reflects the state of the cells constituting the skeletal muscles of the extremities, rather than the trunk muscles [34].

This study had several limitations. First, as this was a single-center study, the generalizability of the results is uncertain.

Second, the causal relationship between the phase angle and sarcopenia is unknown because of the retrospective and cross-sectional nature of the study. Third, factors such as decreased grip strength due to hand pain and deformity, which may influence the prevalence of sarcopenia, were not examined. Fourth, there may have been patients with CTD who did not meet the classification criteria or were not formally diagnosed at the time of rehabilitation. Additionally, there are multiple CTDs, and it is unclear whether this study encompassed all of them. Therefore, it is uncertain whether the association between the phase angle and sarcopenia can be established after focusing on specific diseases such as RA and SSc. Future prospective cohort studies should evaluate whether phase angle values for each disease are associated with the development of sarcopenia and other clinical outcomes, including pain.

## 5. Conclusion

The phase angle is negatively associated with sarcopenia in hospitalized patients with CTDs. The optimal cutoff values of the phase angle for discriminating sarcopenia were 4.6° in men and 4.3° in women. Assessing the phase angle can assist in the identification and management of patients with sarcopenia or those at risk of developing this condition.

## Authors contributions

TM organized and conducted the study, analyzed the data, and wrote the manuscript. MT, RH, AH, HI, MO, and YM collected data. SS secured the grants and supervised the article's writing. All authors contributed to the study's management and reviewed the manuscript. All authors have approved the submitted manuscript and agreed to be accountable for all aspects of the work.

## Funding

This study was supported by the Health Labour Science Research Grants of the Ministry of Health Labour and Welfare (Grant No. 230301-1). The funding body had no role in the study design, data collection and analysis, decision to publish, or manuscript preparation.

## Declaration of competing interest

The authors declare no conflicts of interest.

## Acknowledgments

We thank the medical administrative staff, rehabilitation physicians, and therapists for their invaluable support and contributions to this research.

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## ORIGINAL ARTICLE

# Probable Respiratory Sarcopenia Decreases Activities of Daily Living in Older Patients Hospitalized with Respiratory Diseases: A Cross-sectional Study

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**Objectives:** Respiratory sarcopenia is characterized by low respiratory muscle mass and respiratory muscle strength, but its impact on activities of daily living (ADL) remains unknown. We aimed to investigate the association between respiratory sarcopenia and decreased ADL. **Methods:** This retrospective cross-sectional study included older inpatients ( $\geq 65$  years old) with respiratory diseases who underwent rehabilitation. Because the evaluation of respiratory muscle mass is challenging, probable respiratory sarcopenia was defined according to low appendicular skeletal muscle index ( $< 7 \text{ kg/m}^2$  for men,  $< 5.7 \text{ kg/m}^2$  for women) and peak expiratory flow rate ( $< 4.4 \text{ L/s}$  for men,  $< 3.21 \text{ L/s}$  for women). ADL was assessed on the first day of rehabilitation using the baseline Barthel Index (BI). **Results:** Of 111 inpatients (median age 75 years; 57 women), 13 (11.7%) had probable respiratory sarcopenia. Forty-five patients (40.5%) had sarcopenia and 12 of these had probable respiratory sarcopenia. Pulmonary functions (Forced Vital Capacity and expiratory volume in 1 s) were significantly lower in patients with probable respiratory sarcopenia than those without. Spearman's rank coefficient analysis showed probable respiratory sarcopenia did not significantly correlate with age, phase angle, Charlson Comorbidity Index (CCI), or hemoglobin (Hb). Multivariate linear regression analysis with baseline BI revealed probable respiratory sarcopenia ( $\beta -0.279$  and  $P=0.004$ ) was the significant factor after adjusting for age, sex, body mass index, chronic obstructive pulmonary disease, CCI, and Hb. **Conclusions:** Probable respiratory sarcopenia was independently associated with decreased ADL in patients aged 65 years and older who were hospitalized with respiratory diseases.

**Key Words:** activities of daily living; respiratory diseases; respiratory sarcopenia; sarcopenia

## INTRODUCTION

Respiratory sarcopenia is a medical condition characterized by low respiratory muscle mass and strength.<sup>1,2</sup> It differs from sarcopenia, which is characterized by low appendicular skeletal muscle mass, muscle strength, and physical function.<sup>3</sup> Shortness of breath, dyspnea, reduced coughing ability, and aspiration pneumonia caused by respiratory sarcopenia can result in decreased activities of daily living (ADL). Therefore, it is crucial to assess respiratory

sarcopenia because of the unfavorable impact of low ADL on mortality.<sup>4,5</sup>

Sarcopenia is a risk factor for decreased ADL.<sup>3</sup> The prevalence of sarcopenia in patients with primary lung cancer, interstitial pneumonia, and chronic obstructive pulmonary disease (COPD) is 45%,<sup>6</sup> 32.1%,<sup>7</sup> and 21.6%,<sup>8</sup> respectively. Low respiratory function, which reflects low respiratory muscle strength,<sup>1</sup> is associated with decreased ADL<sup>9</sup> and sarcopenia in older adults.<sup>10</sup> One study found that ADL independence was lower in older adults with sarcopenia and

Received: November 28, 2023, Accepted: March 29, 2024, Published online: April 13, 2024

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low respiratory function than in those with only low respiratory function or robust groups.<sup>11)</sup> These findings suggest that some older patients with respiratory diseases have decreased appendicular skeletal muscle mass and low respiratory function, similar to older patients with sarcopenia. Therefore, respiratory sarcopenia could likely lead to a decline in ADL in patients with respiratory diseases, because many patients may exhibit low respiratory function. In the current study, we aimed to investigate the association between respiratory sarcopenia and decreased ADL in older hospitalized patients with respiratory diseases.

## MATERIALS AND METHODS

### Patients

This retrospective cross-sectional study included 122 patients (aged  $\geq 65$  years) who were hospitalized with respiratory diseases and underwent pulmonary rehabilitation at the University of Occupational and Environmental Health Hospital between February 2022 and January 2023. Typically, patients received rehabilitation for airway clearance, improvement of muscle strength, or improvement in ADL ability. All data were collected from medical records. We considered only hospitalized patients who underwent a physical function evaluation a few days after rehabilitation started and a pulmonary function test within 60 days before or 7 days after rehabilitation started. All patients underwent rehabilitation within 2 weeks after hospitalization. Hospitalized patients with missing data or a history of lung surgery were excluded. This study followed the Declaration of Helsinki and was approved by the Ethics Committee of the University of Occupational and Environmental Health [UOEHCRB20-155]. The study's retrospective nature did not require written consent, but patients were provided with the option to withdraw from the study at any time.

### Spirometry

Physicians in primary departments requested medical technologists to assess the adequacy of respiratory function for surgery, disease severity, and treatment efficacy. Medical technologists conducted the pulmonary function tests using an electronic spirometer (FUDAC-7, Fukuda Denshi, Tokyo, Japan) based on the official guidelines of the Japanese Respiratory Society.<sup>12)</sup> Patients were instructed to firmly hold the mouthpiece connected to the spirometer with their lips and clamp their noses to prevent air leakage. After normal breathing, they were instructed to take a deep inhalation from the maximal expiratory level to the maximal inspira-

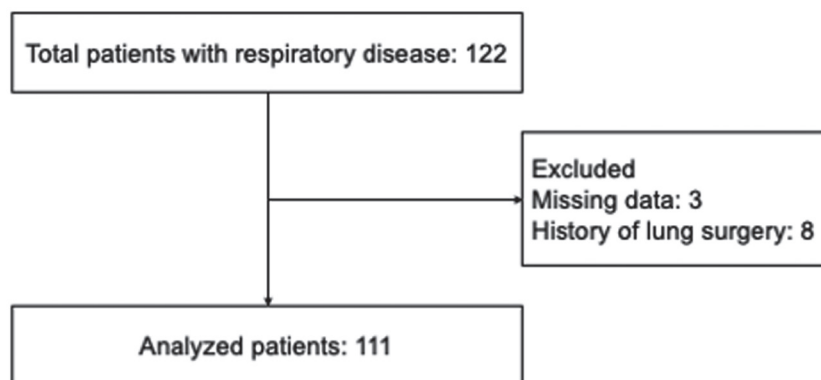
tory level and then forcefully exhale in one continuous breath back to the maximal expiratory level. Practice trials preceded the test, and re-measurements were taken as necessary. The use of bronchodilators or inhaled steroids during the test was documented in the medical records. The forced vital capacity (FVC), forced expiratory volume in 1 s (FEV<sub>1</sub>), and peak expiratory flow rate (PEFR) were assessed. PEFR represents the peak of the flow-volume curve captured by the spirometer, reflecting the highest airflow rate achieved during a forceful exhalation. PEFR is known to decline with age<sup>13)</sup> and is related to respiratory muscle strength<sup>14)</sup> and sarcopenia.<sup>15)</sup>

### Assessment of Physical Function

Physical rehabilitation was prescribed according to the patient's condition and was started on the day of the visit to the Department of Rehabilitation Medicine. Physical function evaluation included handgrip strength, physical function (gait speed, short physical performance battery, or five-time chair stand test), and body composition using a bioimpedance device (InBody S10, InBody, Tokyo, Japan) at least 2 h after eating and after 10 min of rest in the supine position. The InBody S10 enabled the evaluation of the appendicular skeletal muscle index (SMI) and phase angle (PhA) by incorporating age, sex, height, and weight. PhA reflects the resistance and reactance of the whole body and is related to sarcopenia.<sup>16)</sup> The Barthel Index (BI)<sup>17)</sup> was used to evaluate ADL on the day rehabilitation started (baseline BI). The BI comprises scores on a scale of 0–100, with higher scores indicating better ADL functioning. The BI items included (1) feeding, (2) grooming, (3) dressing, (4) transferring, (5) bladder management, (6) bowel management, (7) toileting, (8) bathing, (9) walking, and (10) climbing up and down.

### Definition of Probable Respiratory Sarcopenia and Sarcopenia

Given the paucity of data defining respiratory muscle mass, a more definitive diagnosis of respiratory sarcopenia is needed. However, while it is known that respiratory muscle mass is associated with trunk muscle mass,<sup>18)</sup> there is no clear cutoff value that indicates a reduction in trunk muscle mass. According to a position paper published by four Japanese professional organizations (Society for Respiratory Care and Rehabilitation, Association for Sarcopenia and Frailty, Society of Respiratory Physical Therapy, and Association of Rehabilitation Nutrition),<sup>1)</sup> probable respiratory sarcopenia rather than respiratory sarcopenia can be defined in cases where the appendicular skeletal muscle mass falls



**Fig. 1.** Flowchart of patient recruitment.

below cutoff values defined by the Asian-Working Group for Sarcopenia (AWGS) 2019, which are used as a surrogate for the decline in respiratory muscle mass. To define probable respiratory sarcopenia, we adopted the cutoff values of SMI from AWGS 2019 (SMI  $<7$  kg/m<sup>2</sup> for men and  $<5.7$  kg/m<sup>2</sup> for women)<sup>3)</sup> and cutoff values of low respiratory muscle strength (PEFR  $<4.4$  L/s for men and  $<3.21$  L/s for women) according to a previous report.<sup>15)</sup> To define sarcopenia, we also used the AWGS 2019,<sup>3)</sup> with low appendicular skeletal muscle mass indicated by SMI less than 7 kg/m<sup>2</sup> for men and less than 5.7 kg/m<sup>2</sup> for women, in combination with low muscle strength as indicated by at least one of the following: low handgrip strength ( $<28$  kg for men or  $<18$  kg for women), low physical performance (gait speed  $<1$  m/s), short physical performance battery ( $\leq 9$  points), or slow five-time chair stand test ( $\geq 12$  s).

### Collecting Other Data

Respiratory disease types were categorized into primary lung cancer, interstitial pneumonia, COPD, asthma, and other diseases. We investigated age, sex, body mass index (BMI), comorbidities, history of stroke, the Charlson Comorbidity Index (CCI),<sup>19)</sup> Brinkman Index,<sup>20)</sup> serum albumin, hemoglobin (Hb), C-reactive protein levels (CRP), and preadmission orientation. The CCI, serum albumin, Hb, and CRP were recorded at admission.

### Statistical Analysis

Statistical analyses were performed using SPSS Version 27 (IBM SPSS Japan, Tokyo, Japan); the bilateral test set  $P < 0.05$  as statistically significant. Categorical variables were expressed as number (percentage), whereas quantitative variables were expressed as median [interquartile range] or mean (standard deviation) according to the normality of

the Shapiro–Wilk test. Categorical variables were analyzed using the chi-square test and Fisher’s test to compare older patients with and without probable respiratory sarcopenia. Quantitative variables were subjected to the t-test and Mann–Whitney U test based on the normality of the Shapiro–Wilk test.

Spearman’s rank correlation coefficient analysis evaluated the association among probable respiratory sarcopenia, age, BMI, CCI, PhA, Hb, and baseline BI. Age,<sup>3)</sup> BMI,<sup>3)</sup> CCI,<sup>21)</sup> PhA,<sup>16)</sup> and Hb<sup>22)</sup> have been reported to be associated with sarcopenia. To investigate the association between ADL and probable respiratory sarcopenia, we performed multivariate linear regression analysis of baseline BI with age, sex, BMI, COPD, CCI, Hb, and probable respiratory sarcopenia. The Variance Inflation Factor (VIF) among factors in the multivariate linear regression model was then calculated. Comorbidity is associated with decreased ADL in older adults.<sup>23)</sup> BMI<sup>24)</sup> and Hb<sup>25)</sup> are also associated with decreased ADL. Given that multivariate linear regression analysis necessitates a minimum of 15 cases per independent variable, this study required at least 105 cases to accommodate the seven variables in the model. Multicollinearity was assessed using the VIF, where a VIF value between 1 and 3 indicates the absence of multicollinearity.

## RESULTS

A total of 122 hospitalized patients (aged  $\geq 65$  years) with respiratory diseases were evaluated; 3 patients were excluded because of missing data and 8 were excluded because of previous lung surgery (**Fig. 1**). Therefore, this study included 111 patients with respiratory diseases [median age, 75 years; 57 women (51.4%)]. Respiratory disease types included primary lung cancer ( $n=59$ ), interstitial pneumonia ( $n=52$ ),



COPD (n=10), asthma (n=6), and others (n=9). Others were metastatic lung tumors (n=5), benign lung tumors (n=2), and mediastinal tumors (n=2).

Seven patients had primary lung cancer and interstitial pneumonia, and 9 patients had primary lung cancer and COPD. Twenty patients regularly used bronchodilators or inhaled steroids at the time of the pulmonary function test, but no patients used them during the pulmonary function test to assess airway reversibility. In total, 68 patients were in the preoperative stage for surgery. The number of patients with probable respiratory sarcopenia was 13 (11.7%), and 12 of them had sarcopenia. Forty-five (40.5%) had sarcopenia, and 27 of them had low PEFR.

**Table 1** shows the characteristics and comparisons of patients with probable respiratory sarcopenia and those without probable respiratory sarcopenia. Patients with probable respiratory sarcopenia had a higher incidence of COPD ( $P=0.022$ ), lower BMI ( $P=0.004$ ), more regular use of bronchodilators or inhaled steroids ( $P=0.002$ ), lower handgrip strength ( $P<0.001$ ), lower SMI ( $P<0.001$ ), more cases of sarcopenia ( $P<0.001$ ), and lower scores on the baseline BI ( $P=0.007$ ) than patients without probable respiratory sarcopenia. PhA tended to be lower in patients with probable respiratory sarcopenia than in patients without ( $P=0.068$ ). In the pulmonary function tests, patients with probable respiratory sarcopenia exhibited lower FVC, FEV<sub>1</sub>, and PEFR ( $P<0.013$ ,  $P<0.001$ , and  $P<0.001$ , respectively) than patients without probable respiratory sarcopenia. However, no significant difference was observed in the FEV<sub>1</sub>/FVC ratio between patients with and without probable respiratory sarcopenia ( $P=0.155$ ).

Spearman's rank correlation coefficient analysis showed that probable respiratory sarcopenia had a significant correlation with BMI ( $\rho -0.274$ ,  $P=0.004$ ) and baseline BI ( $\rho -0.255$ ,  $P=0.007$ ) but no significant correlation with sarcopenia-related factors such as age ( $\rho 0.13$ ,  $P=0.174$ ), CCI ( $\rho 0.122$ ,  $P=0.205$ ), PhA ( $\rho -0.174$ ,  $P=0.068$ ), and Hb ( $\rho -0.066$ ,  $P=0.494$ ). A multivariate linear regression analysis with the baseline BI (adjusted  $R^2=0.173$ ,  $P<0.001$ ) revealed that probable respiratory sarcopenia ( $\beta -0.279$ ,  $P=0.004$ ) was the significant factor after adjusting for age, sex, BMI, COPD, CCI, and Hb (**Table 2**). Multicollinearity was not observed among them.

## DISCUSSION

This study investigated the association between probable respiratory sarcopenia and ADL in patients aged 65 years or over who were referred to our Department of Rehabilitation

Medicine for treatment of respiratory diseases. The prevalence of probable respiratory sarcopenia in these patients was 11.7%, based on our operational definition. We found that probable respiratory sarcopenia was independently associated with decreased ADL. Based on our definition of probable respiratory sarcopenia that we adopted from a position paper by four Japanese health organizations,<sup>1)</sup> we believe this study to be the first to associate probable respiratory sarcopenia with decreased ADL in older inpatients with respiratory diseases.

The position paper on the diagnosis of respiratory sarcopenia<sup>1)</sup> recommends evaluating respiratory muscle mass by ultrasonography or computed tomography and respiratory muscle strength based on the maximal inspiratory and/or expiratory pressure in the pulmonary function test. For cases in which the assessment of respiratory muscle mass is challenging, the appendicular skeletal muscle mass can be used to determine respiratory muscle mass, and probable respiratory sarcopenia can be diagnosed. PEFR, peak cough flow, and sniff nasal inspiratory pressure can be used to evaluate respiratory muscle strength. However, low respiratory muscle strength cutoff values still need to be established. There are few studies on the association between sarcopenia and low PEFR<sup>9,15)</sup> in older adults. Kera et al.<sup>15)</sup> set the cutoff values in the PEFR for respiratory sarcopenia (4.4 L/s for men and 3.21 L/s for women) as the only indicator of respiratory muscle strength to confirm sarcopenia and long-term care insurance among community-dwelling older adults. Therefore, following the algorithm definition of four Japanese health organizations for probable respiratory sarcopenia,<sup>1)</sup> we used SMI cutoff values for low appendicular skeletal muscle mass (7 kg/m<sup>2</sup> for men and 5.7 kg/m<sup>2</sup> for women) and PEFR cutoff values for low respiratory function (4.4 L/s for men and 3.21 L/s for women) based on previous reports.<sup>3,15)</sup>

PEFR is influenced by airway stenosis.<sup>26)</sup> Our study showed no difference in the FEV<sub>1</sub>/FVC ratio between patients with and without probable respiratory sarcopenia. Furthermore, FVC and FEV<sub>1</sub> were lower in patients with probable respiratory sarcopenia. Therefore, despite the impact of airway obstruction on PEFR, the findings suggest that respiratory muscle strength is lower in patients with probable respiratory sarcopenia than those without it.

The prevalence of sarcopenia among those with probable respiratory sarcopenia is expected, given that SMI is used as a surrogate for respiratory muscle mass. However, this study revealed that probable respiratory sarcopenia did not significantly correlate with potential factors associated with sarcopenia, such as age, PhA, or Hb. PhA has been reported



**Table 1.** Patient characteristics and comparison between patients with and without probable respiratory sarcopenia

	Overall (n=111)	With probable RS (n=13)	Without probable RS (n=98)	P value
Age, years	75 [71–81]	78 [74.5–81.5]	75 [70.5–81]	0.172
Sex, female	57 (51.4%)	7 (53.8%)	50 (51%)	0.848
BMI, kg/m <sup>2</sup>	23 [20.6–25.2]	20.1 [19.1–22.3]	23.3 [21–25.4]	0.004
Respiratory disease				
Primary lung cancer	59 (53.2%)	9 (69.2%)	50 (51%)	0.23
Interstitial pneumonia	52 (46.8%)	3 (23%)	49 (50%)	0.063
COPD	10 (14.4%)	3 (23%)	7 (7.1%)	0.022
Asthma	6 (5.4%)	2 (11.7%)	4 (3.6%)	0.147
Others	9 (8.1%)	1 (0.9%)	8 (8.1%)	0.712
Comorbidities				
Hypertension	52 (46.8%)	6 (46.2%)	46 (46.9%)	1
Diabetes mellitus	27 (24.3%)	2 (15.4%)	25 (25.5%)	0.731
Chronic heart failure	7 (6.3%)	1 (7.7%)	6 (6.1%)	0.593
Atrial fibrillation	8 (7.2%)	1 (7.7%)	7 (7.1%)	1
Kidney failure	12 (10.8%)	2 (15.4%)	10 (10.2%)	0.631
Cancer, other than lung	15 (13.5%)	1 (7.7%)	14 (14.3%)	1
Connective tissue disease	50 (45%)	4 (30.8%)	46 (46.9%)	0.271
History of stroke	9 (8.1%)	3 (23.1%)	6 (6.1%)	0.07
CCI	2 [1–3]	3 [0.5–3.5]	2 [1–3]	0.203
Bronchodilators or inhaled steroids use	20 (18%)	7 (53.8%)	13 (13.3%)	0.002
Brinkman Index	495 [0–992]	660 [367–1240]	400 [0–900]	0.058
Low handgrip strength	69 (62.1%)	12 (17.4%)	57 (82.6%)	0.017
Low SMI	51 (45.9%)	13 (100%)	38 (38.8%)	<0.001
Sarcopenia	45 (40.5%)	12 (92.3%)	33 (33.7%)	<0.001
PhA, °	4.5 [3.7–5.1]	4.2 [3.6–4.4]	4.5 [3.7–5.2]	0.068
FVC, L	2.34 (0.89)	1.76 (0.57)	2.41 (0.88)	0.013
FEV <sub>1</sub> , L	1.69 (0.59)	1.09 [0.76–1.37]	1.72 [1.34–2.19]	<0.001
FEV <sub>1</sub> /FVC, %	75.1 (13.6)	79.8 [72.6–88.6]	71.6 [65.8–82.6]	0.155
PEFR, L/s	5.24 [3.93–6.82]	2.96 [2.43–3.04]	5.55 [4.28–7.41]	<0.001
Low PEFR	40 (36%)	13 (100%)	27 (27.5%)	<0.001
Serum albumin, g/dL	3.8 [3.5–4.2]	3.7 [3.4–4.1]	3.9 [3.5–4.2]	0.541
Hb, g/dL	12.3 [11–13.8]	12.3 [10.3–13.6]	12.4 [11.1–13.9]	0.491
CRP, mg/dL	0.24 [0.06–0.88]	0.24 [0.13–0.66]	0.24 [0.06–0.94]	0.945
Baseline Barthel Index	95 [85–100]	65 [55–100]	100 [90–100]	0.007
Preadmission orientation				
Home	106 (95.6%)	11 (84.6%)	95 (96.9%)	0.104
Nursing home	3 (2.7%)	1 (7.7%)	2 (2%)	
Another hospital	2 (1.8%)	1 (7.7%)	1 (1%)	

Categorical variables are given as number (percentage); quantitative variables are given as median [interquartile range]; some data for FVC and FEV<sub>1</sub> given as mean (standard deviation). CCI, serum albumin, Hb, and CRP were assessed at admission. BMI, handgrip strength, SMI, and PhA were assessed a few days after rehabilitation started. Baseline BI was assessed on the first day of rehabilitation.

RS, respiratory sarcopenia.

**Table 2.** Multivariate linear regression analysis of probable respiratory sarcopenia with baseline BI

	B	$\beta$	95% confidence interval	P value	VIF
Probable respiratory sarcopenia	-16.118	-0.279	-26.904 to -5.333	0.004	1.155
Age	-0.365	-0.123	-0.889 to 0.158	0.169	1.031
Female	-6.732	-0.179	-13.502 to 0.037	0.051	1.08
BMI	0.627	0.126	-0.276 to 1.530	0.917	1.091
COPD	6.558	0.101	-5.260 to 18.376	0.274	1.10
CCI	-1.174	-0.095	-3.366 to 1.017	0.290	1.052
Hb	0.342	0.136	-0.099 to 0.784	0.127	1.052

Adjusted  $R^2=0.173$ ,  $P<0.001$ . CCI and Hb were recorded at admission. Baseline BI was assessed on the first day of rehabilitation.

as a useful indicator of sarcopenia in various studies.<sup>16,27)</sup> In our results, patients with probable respiratory sarcopenia tended to have lower PhA values than those without, indicating a potential negative association. However, these trends did not reach statistical significance. Although PhA is associated with grip strength and skeletal muscle mass,<sup>16,27)</sup> its relationship with respiratory function remains to be elucidated. Consequently, our findings did not conclusively determine the relevance of PhA to PEFR. This highlights the need for further research to clarify the role of PhA in assessing respiratory muscle strength and function.

Patients with respiratory diseases experience a limited capacity to perform ADL because of respiratory symptoms.<sup>28,29)</sup> However, it is difficult to demonstrate a decline in ADL using comprehensive ADL assessment scales,<sup>30)</sup> such as the BI. Because of the adverse effects of severe dyspnea on motor endurance and subsequent decreased ADL, assessment tools that incorporate the degree of dyspnea have been developed.<sup>31,32)</sup> Given that respiratory function reflects respiratory symptoms, probable respiratory sarcopenia might indicate respiratory symptoms and help detect a statistically significant decline in the comprehensive ADL. Although the adjusted coefficient of determination of the multivariate regression model in this study did not fit well, the standardized partial regression coefficient for probable respiratory sarcopenia indicated that it was closely related to decreased ADL.

“Sarcopenic respiratory disability” defines functional disability resulting from reduced respiratory function caused by respiratory sarcopenia.<sup>2)</sup> However, our study has not conclusively shown significant impairment caused by respiratory muscle sarcopenia. More research is needed to understand its impact on respiratory function and functional disability.

## LIMITATIONS

This study has some limitations. First, the diagnosis of respiratory sarcopenia in this study was probable rather than definitive. The concept of “probable respiratory sarcopenia” was operationalized because of the need for established diagnostic criteria and the paucity of data directly defining respiratory muscle mass. As a result, our results should be interpreted with the understanding that they do not provide a definitive diagnosis of respiratory sarcopenia but rather an association with ADL limitations based on a probable condition associated with decreased respiratory muscle mass and function. Further research is required to refine the diagnostic criteria for respiratory sarcopenia, allowing for a more definitive respiratory muscle mass and understanding its impact on ADL. Second, the generalizability of the study is limited because of its retrospective and single-center design. Third, the causal association between probable respiratory sarcopenia and decreased ADL was not addressed because of the retrospective cross-sectional nature of the study. Fourth, many of the included patients were in the preoperative stages of lung cancer. This may have introduced a potential selection bias because these patients differ from patients with common respiratory diseases. Fifth, because not all evaluations were conducted within a few days, each evaluation might have incurred pathological alterations.

## CONCLUSION

The results of this study showed that probable respiratory sarcopenia was independently associated with decreased ADL in patients aged 65 years and over who were hospitalized with respiratory diseases. Further investigations are warranted to establish the parameters and threshold values from pulmonary function tests that can accurately delineate

low respiratory muscle strength, thereby providing definitive diagnostic criteria for respiratory sarcopenia.

### ACKNOWLEDGMENTS

The authors thank the rehabilitation therapists of the University of Occupational and Environmental Health Hospital for their support in conducting the study. This study was supported by a Health and Labour Sciences Research Grant from the Ministry of Health, Labour, and Welfare of Japan (Grant number 230301-1).

### CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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## 【別紙資料28】



## 勤労者世代における腰部脊椎疾患における 手術状況及びその影響の後方視的調査

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樋口周人  
蜂須賀明子 伊藤英明 佐伯寛

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

### 要 旨

勤労者の腰椎手術施行者について、どのような職種に多いか、各職種における術後の復職率、腰椎立位アライメントの特徴は明らかでない。今回、当院整形外科に手術目的で入院した勤労者世代の腰部脊椎疾患の患者特性を調査した。腰部脊椎疾患で手術に至った症例は、肉体労働者に多く(54.6%)、腰椎立位矢状面上のアライメントは職種で異なる特徴を認めた。職種に応じた対策の重要性が示唆された。

#### 【はじめに】

腰痛は、勤労者世代から高齢者全世代において本邦における有訴率が高い疾患である(厚生労働省, 2019)。また勤労者における腰痛は、休職及び生産性の低下による経済的損失が多いだけでなく、発症者の一定数が手術まで移行すると報告されている(Keeney BJ, et al. 2013)。どのような職種および年代において、腰椎を中心とした脊椎疾患を引き起こし、手術まで至るのかは明確になっていない。そこで、今回当院整形外科に手術目的で入院加療し、リハビリテーションが処方された腰部脊椎疾患患者の特徴を後方視的に調査した。

#### 【対 象・方法】

2019年から2021年の3年間で当院整形外科に手術目的で入院加療し、リハビリテーションが処方された腰部脊椎疾患患者のうち、生産年齢世代(20歳～65歳)66名を解析対象とした。本研究は、カルテによる情報を収集する後方視的横断研究である。

#### 【調査項目】

- 1)患者特性 年齢、身長、体重、Body Mass Index(BMI)、喫煙歴、生活習慣病の有無
- 2)疾患特性 疾患名、罹患期間、手術方法、画像所見、神経症状の有無、腰痛の程度(Visual Analogue Scale)  
画像所見:Sagittal Vertical Axis(SVA)、腰椎前弯角(LL)、Pelvic Incidence(PI)、PI-LL
- 3)就業状況 入院時の就業の有無、職種、復職の可否及び時期 \*職種:肉体労働、デスクワーク、サービス業

#### 【統計解析】

- ①記述統計量 各調査項目 ②職種間での比較 一元配置分散分析または $\chi^2$ 検定 有意水準 5%

#### 【結 果】

##### ①腰部脊椎疾患の手術患者における職種内訳と復職

職種内訳:  
肉体労働 54.6%、デスクワーク 22.7%、サービス業 22.7%

復職率:92.7%(平均復職期間3.4±3.0カ月、最長14カ月)

##### ②患者特性

	全体 (n=66)	肉体労働 (n=36)	デスクワーク (n=15)	サービス業 (n=15)
患者特性				
年齢(歳)	48.63±13.48	46.92±14.45	53.73±11.70	45.80±12.65
性別(男性%)	66.7	66.7	86.7	40.0
身長(cm)	166.25±10.46	163.96±11.26	173.98±5.59	163.25±9.14
体重(kg)	72.44±14.84	72.99±17.35	73.81±9.11	70.43±15.29
Body Mass Index	25.73±5.09	26.14±6.11	24.47±3.23	26.31±4.51
喫煙歴(有%)	68.1	69.4	60.0	66.7
生活習慣病(有%)	36.2	41.7	40.0	13.3
医学所見				
疾患名(%)				
脊柱管狭窄症	39.1	44.4	46.7	20.0
ヘルニア	40.6	36.1	20.0	73.3
すべり症	14.5	11.1	26.7	6.7
その他	5.8	8.4	6.6	0.0
術式(%)				
形成術	46.4	47.2	60.0	33.3
固定術	26.1	27.8	26.7	20.0
摘出術	27.5	25.0	13.3	46.7
罹患期間(月)	22.24±39.76	25.63±45.21	27.53±46.34	12.13±17.22
VAS(mm)	44.93±27.41	50.65±24.38	43.30±34.11	33.90±22.40

平均値±標準偏差

#### 【考察】

##### ①腰部脊椎疾患の手術患者における職種内訳と復職

術前の就業率は83.5%、復職率は92.7%、復職までの期間3.3か月  
手術に至った者のうち、肉体労働の占める割合が高かった

- ・腰椎固定術後2年の復職率は、19～39%  
Lewin AM. 2021  
Mayer TG. 2014
- ・勤労者の腰痛発症は、肉体労働者、デスクワーク、技術職が多い  
Jiang X, et al. 2018

復職率は先行研究と比較して高値

\*本研究では、短期的なフォローアップ、労働災害者は含まれていない

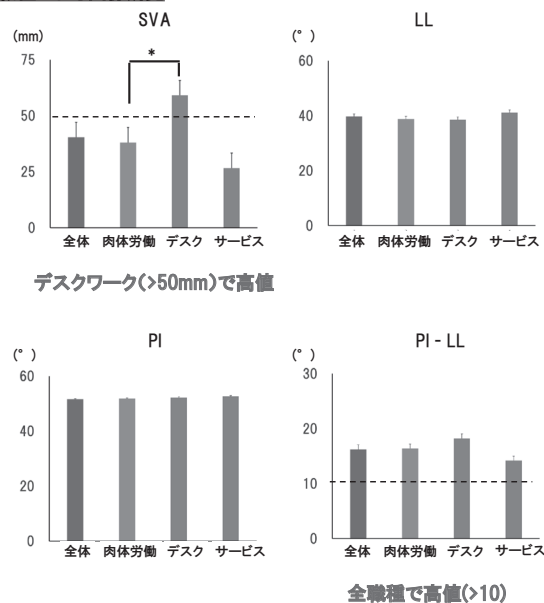
#### 【限界】

- ・症例数が少ないこと
- ・選択バイアスが生じていること
- ・後方視的研究であること
- ・職種の分類について

#### 【展望】

- ・症例数を増やし、腰痛予防対策としての画像所見の有用性を検討する
- ・職種ごとにおける対策が、有効か検討する

##### ③職種による画像所見



##### ②腰椎立位矢状面上のアライメント異常の特徴と職種

全職種においてPI-LL高値で、腰椎のアライメント異常を認めた  
デスクワークのみ、SVA高値であった

- ・矢状面上でのアライメントが、腰部疼痛に影響  
Glassman SD, et al. 2005
- ・介護職者の腰痛には、画像上のアライメントが影響を与えなかった  
片山, 他. 2018
- ・肉体労働者は、重症化リスクが高く、1時間以上中腰姿勢が腰痛に影響  
Ishimoto Y, et al. 2019

腰椎矢状面のアライメントは職種により異なり、業務自体が腰部のストレス  
腰痛及び手術移行の予防は、職種に応じた対策の重要性を示唆

# 北九州脳卒中地域連携パスデータに登録 されている患者の性差

Difference of gender of stroke patients in the critical pathway in Kitakyushu

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# 一般口演 10 (卒中O10) 臨床研究 北九州脳卒中地域連携パスデータに 登録されている患者の性差

産業医科大学

下鶴 幸宏

筆頭演者は日本脳卒中学会へ過去3年間のCOI自己申告を完了しています。

本演題の発表に際して開示すべきCOIはありません。

## 背景

- 北九州脳卒中地域連携パス（連携パス）は、2009年より運用を開始し、北九州周辺地域の脳卒中診療の均てん化に向けた、地域医療機関の連携システムとして利用されている。
- 脳卒中の性差については、国内外問わず研究がなされている。
- 北九州地域の脳卒中患者の特徴を知るために、連携パスの解析を通して脳卒中患者の性差について調査をした。

# 研究方法

## 【対象】

連携パス参加病院（急性期・回復期・維持期）で、入院後7日以内もしくは診療開始7日以内に患者および家族から北九州脳卒中地域連携パス使用の同意を得た患者。

## 【解析項目】

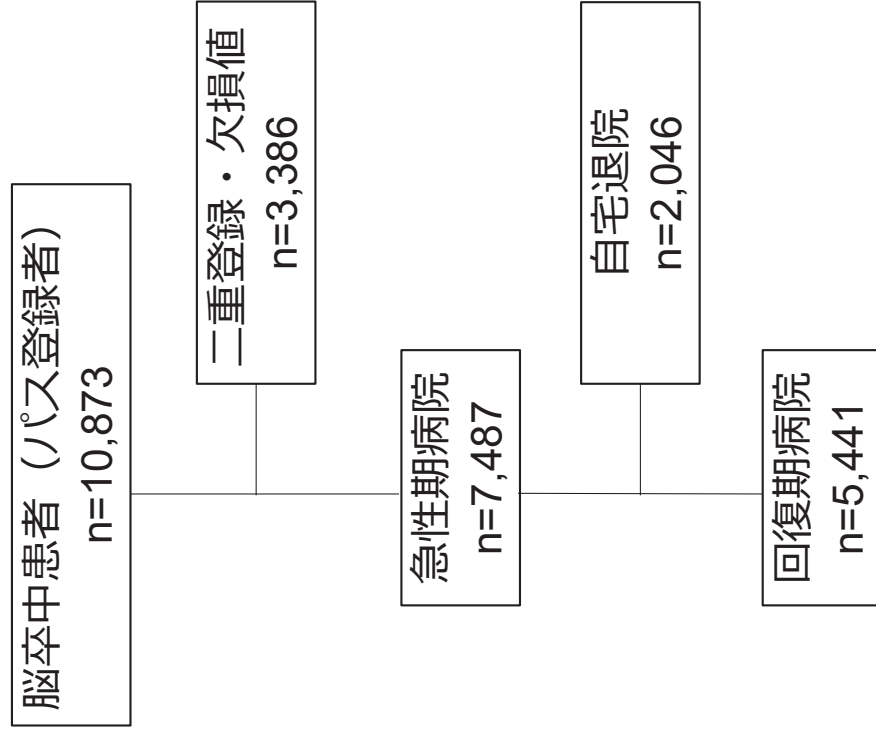
発症時年齢・脳卒中の病型・平均在院日数・日常生活機能について、男女別に比較した。

## 【期間】

2009年4月1日から2021年12月31日。

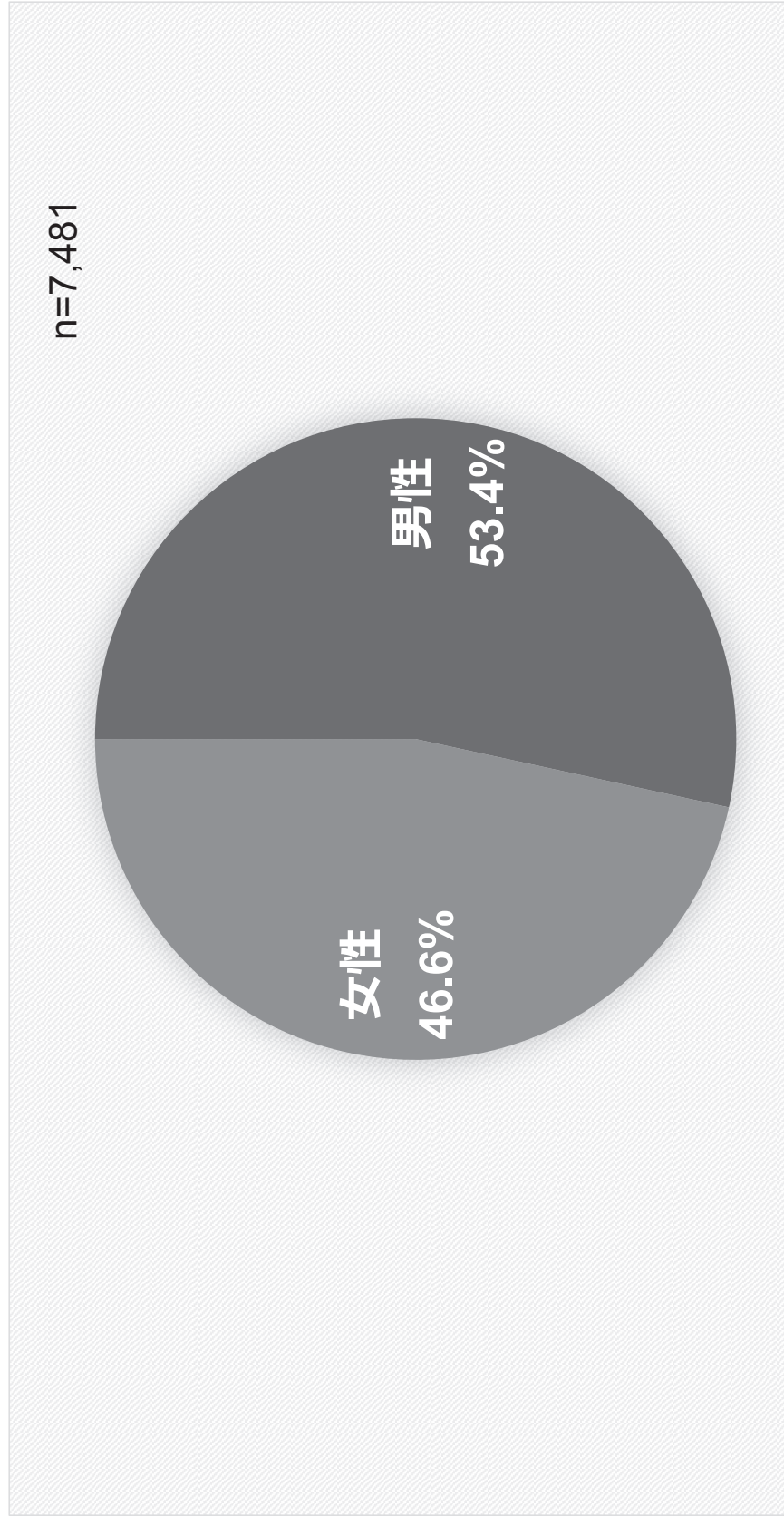
## 【統計ソフト】

SPSS version 27.0 for Windows を用いた。  
有意水準は $P<0.05$ とした。





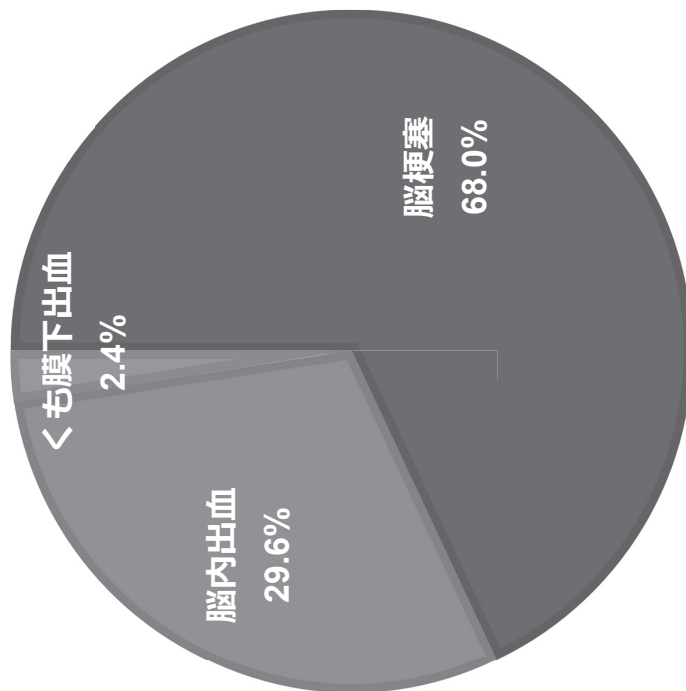
## 結果：男女比



# 結果：病型割合

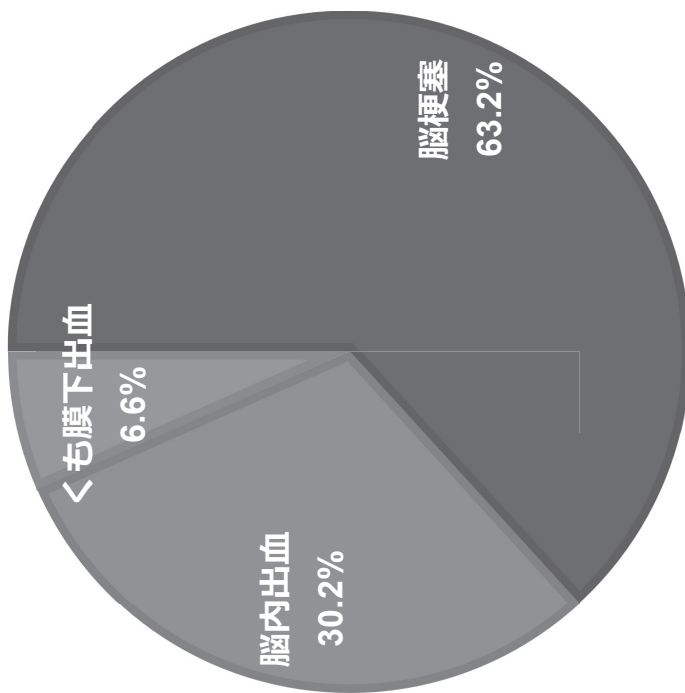
男性

n=3,996



女性

n=3,485



# 結果：基本属性

	男性 (n=3,996)		女性 (n=3,485)	
	平均値	標準偏差	平均値	標準偏差
発症時年齢	72.2	12.0	77.4	11.5
在院日数	急性期病院	27.4	急性期病院	29.6
	回復期病院	87.5	回復期病院	97.9
FIM（回復期病院）	入院時	70.9	入院時	62.8
	退院時	91.4	退院時	82.8
	FIM利得	20.0	FIM利得	19.5
		18.8		32.4
				36.4
				19.1

# 結果：t検定

	男性			女性			
	n	平均	標準偏差	n	平均	標準偏差	p 値
年齢	3989	72.2	12.0	3480	77.4	11.5	<0.001
在院日数 (急性期病院)	3959	27.4	16.8	3447	29.6	30.5	0.006
在院日数 (回復期)	2802	87.5	60.7	2427	97.9	81.8	0.157
NIHSS (急性期病院退院時)	3460	6.1	6.1	3038	7.4	7.3	<0.001
FIM合計点 (回復期病院入院時)	2530	91.4	34.1	2204	82.8	36.4	<0.001
FIM合計点 (回復期病院退院時)	2071	70.9	33.1	1800	62.8	32.4	0.541
FIM利得	2054	20.0	18.8	1788	19.5	19.1	0.775

## 考察：発症時年齢

- 北九州市は、高齢化率31.2%と政令指定都市で最も高く、女性の健康寿命は政令指定都市の中で5番目に長い（令和1年）。（北九州市, 2024）
- 女性は中年以降でエストロゲンの影響により、動脈硬化の進行を加速させる。さらに加齢に伴い脳卒中の発症リスクが上昇する。（井川ら, 2017）

**高齢化率の高さ、健康寿命と平均寿命の延伸が発症年齢を引き上げている要因として考えられる。**



# 考察: 脳出血の割合

脳出血患者数 (%)

	本データ	全国
男性	29.6	19.4
女性	30.2	20.0

男女とも、全国データより脳出血の割合が多い傾向にある。

(Toyoda et al, 2021)

- 福岡県における男性の高血圧症有病者は、全国平均より高い。 (福岡県, 2023)  
男性：福岡県63.4%、全国57.4%

- 脳アミロイドアンギオパチーによる脳出血の発症年齢は73.2歳であり、高齢に伴い患者数が増加する。 (Hirohata et al, 2010)

**脳出血の割合が多い理由として、高血圧や、脳アミロイドアンギオパチーによる影響が考えられる。**

## 考察：重症度・在院日数

- 脳卒中の重症度は、女性で高くなる傾向にある。（Reeves et al, 2008）
- 急性期・回復期病院とも女性の在院日数は延長し、回復期病院入院時のFIM合計点は低かった。

**本パスデータでも女性の重症度が高い傾向がみられた。**

## 結語

北九州地域連携パスの解析を通して、北九州地域における脳卒中患者の性差について調査をした結果、以下の特徴を認めた。

- 女性の発症時年齢が高かった。
- 男女とも脳出血割合が多かった。
- 急性期・回復期病院とも女性は男性より在院日数は延長していた。
- 男性より女性の重症度が高かった。



Contents lists available at ScienceDirect

Journal of Stroke and Cerebrovascular Diseases

journal homepage: [www.elsevier.com/locate/jstroke](http://www.elsevier.com/locate/jstroke)

## Survey of patients with stroke in the Kitakyushu Area, Japan: a 12-year retrospective analysis of the critical pathway

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### ARTICLE INFO

#### Keywords:

Stroke  
Severity  
Convalescent hospital  
Critical pathway  
Aging Society

### ABSTRACT

**Objectives:** We aimed to clarify the incidence, clinical profile, outcome, and activities of daily living of patients with stroke using the Kitakyushu clinical pathway database and to investigate the characteristics of patients with stroke in the Kitakyushu medical area in Japan.

**Materials and Methods:** The clinical data of patients with stroke registered in the Kitakyushu database between April 1, 2009 and December 31, 2021 were retrospectively examined. The National Institutes of Health Stroke Scale was used to classify stroke severity. A descriptive analysis of basic variables, including age, stroke type, length of hospital stay, and activities of daily living, according to stroke severity was conducted.

**Results:** There were 7,487 acute care hospital patients and 5,441 rehabilitation hospital patients. Compared with patients in similar cities in Japan, patients in the Kitakyushu area tended to be older at the time of stroke onset with a higher proportion of cases of hemorrhagic stroke. Length of hospital stay in both acute and rehabilitation hospitals increased with stroke severity. The Functional Independence Measure gain was highest in patients with moderate disability.

**Conclusions:** Compared with patients in similar cities in Japan, in the Kitakyushu area, patients with stroke were older and the proportion of patients with hemorrhagic stroke was higher. Stroke rehabilitation therapy is effective for patients with moderately severe stroke.

### Introduction

It is predicted that the population aged  $\geq 70$  years in European Union countries will increase to 23% of the total population in 2047 compared with 14% in 2017, with a 4% increase in the incidence of stroke and a 27% increase in the prevalence of stroke cases<sup>1</sup>. In the United States, the incidence of stroke increases every 10 years among the population aged  $>45$  years, and those aged  $\geq 65$  years account for 70% of stroke cases<sup>2</sup>. Similarly, in Japan, there has been a rapid increase in the incidence of stroke among the population aged  $\geq 45$  years<sup>3</sup>, and the lifetime risk of stroke after the age of 45 years is increasing<sup>4</sup>. Therefore, there is an urgent need to implement preventive measures against stroke in Japan. According to recent data, the incidence of stroke in Japan has been decreasing, with the number of cases per 1,000 people per year dropping from 14.34 for men and 7.19 for women in the 1960s to 4.22 for men and 2.22 for women in the 2000s<sup>5</sup>.

The Kitakyushu region, which is the focus of this research, is part of Fukuoka Prefecture and includes Kitakyushu City, the second largest city in Fukuoka Prefecture, with a population of approximately 930,000<sup>6</sup>. It is estimated that among the 2022 ordinance-designated cities in Japan, Kitakyushu has the highest ratio of older adults aged  $\geq 65$  years, reaching 31.2%<sup>6</sup>.

In Japan, it is necessary to respond to the increasing healthcare costs and the predicted decrease in resources available to fund healthcare services due to a declining birth rate and an aging population<sup>7</sup>. Therefore, in accordance with the 2007 revision of the 5th Medical Care Law, nationwide efforts are being made to build a seamless medical system from patient hospitalization to discharge to home. Kitakyushu City began operating the Kitakyushu Stroke Liaison Critical Pathway in 2009 and is working to improve regional medical care. A liaison critical pathway is an information tool for intra- and inter-hospital collaboration. By understanding patients' conditions from admission to

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<https://doi.org/10.1016/j.jstrokecerebrovasdis.2023.107525>

Received 21 May 2023; Received in revised form 29 November 2023; Accepted 1 December 2023

Available online 2 January 2024

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hospitalization to discharge, each medical institution can alleviate the anxiety of patients and their families and encourage them to participate in treatment. In 2018, The Cerebrovascular and Cardiovascular Disease Control Act was enacted in Japan promoting strategies for preventing cardiovascular diseases, including stroke and myocardial infarction, and promoting the development of prompt and appropriate treatment systems to extend healthy life expectancy and reduce medical and nursing care costs<sup>8</sup>. Understanding current stroke trends in the Kitakyushu region, which has a large proportion of older adults, is important in predicting the requirements for stroke care in Japan and other countries with an aging population in the future.

This study aimed to clarify subtype rates, clinical features, outcome destination, and daily living functions among patients with stroke in the Kitakyushu area using the data of the Kitakyushu Stroke Liaison Critical Pathway. In addition, this study aimed to determine the characteristics of patients with stroke admitted to hospitals in the Kitakyushu area.

## Methods

### Kitakyushu Stroke Liaison Critical Pathway

In Kitakyushu City, the need for cooperation between hospitals specializing in stroke care has increased in recent years, and owing to the cooperation among the Kitakyushu City Health and Welfare Bureau, the Kitakyushu Medical Association, and the Department of Rehabilitation Medicine at the University of Occupational and Environmental Health, Kitakyushu Stroke Liaison Critical Pathway was introduced in April 2009. Currently, 14 and 37 medical institutions for acute and post-recovery care, respectively, participate in the project, providing stroke care in Kitakyushu City and neighboring areas and contributing to improving regional cooperation. At hospitals providing patient care for each stage of illness (acute care, convalescent, and chronic stages), a pass sheet is completed and mailed to the Kitakyushu Medical Association Secretariat at the University of Occupational and Environmental Health, Japan. Patients are admitted to acute care hospitals during the acute and subacute phases, subsequently the convalescent hospitals provide rehabilitation therapy for the patients during the recovery or convalescent phase. Data items include basic characteristics (age at disease onset, sex, length of hospital stay, and outcome destination), diagnosis, disease severity, disability, and daily living function. At the secretariat, the collected pass sheets are converted using tabulation software, and data are entered into the database. The data are anonymized, so the participant cannot be identified, and stored at the secretariat.

### Participants

We targeted patients admitted for ischemic and hemorrhagic stroke between April 1, 2009, and December 31, 2021, for whom we could obtain consent for access to the Kitakyushu Stroke Liaison Critical Pathway (either from the patient or their family) within 7 days of admission or within 7 days of the attending physician initiating treatment at each hospital (acute care, convalescent, and long-term care facilities).

### Descriptive statistics

Descriptive statistics were performed for the age at onset, male-to-female ratio, length of stay in acute care and convalescent hospitals, Functional Independence Measure (FIM) score at admission and discharge, FIM gain, subtype ratio, and discharge destination. Data on age at onset, length of hospital stay, and FIM gain were calculated separately for acute care and convalescent hospitals. The annual changes in the length of stay in acute and convalescent hospitals between 2009 and 2021 were plotted on a graph. The FIM gain was calculated by subtracting the total FIM score on admission to the

convalescent hospitals from the total FIM score on discharge from the convalescent hospitals.

### Comparison by stroke severity

Stroke severity was classified as previously described<sup>9</sup>, using the National Institute of Health Stroke Scale (NIHSS) outcome prediction at the time of discharge from the acute care hospital: mild (NIHSS score, <5), moderate (NIHSS score, 6–13), and severe (NIHSS score, ≥14). After classifying stroke severity, we calculated the length of stay in acute care and convalescent hospitals, subtype ratio, total FIM score on discharge from convalescent hospitals, and FIM gain.

### Correlation analysis

Correlation coefficients were calculated using the length of stay in convalescent hospitals and the FIM score on discharge from convalescent hospitals as dependent variables. Independent variables for the length of stay in convalescent hospitals and the FIM score on discharge from convalescent hospitals were selected based on previous reports<sup>10, 11</sup>. Length of stay in convalescent hospitals was assessed based on sex, age, outcome destination from convalescent hospitals, Japan Coma Scale (JCS) score on discharge from acute care hospitals, NIHSS score on discharge from acute care hospitals, and presence or absence of long-term care insurance (at the acute care hospital). The JCS classifies the level of consciousness into nine levels in the acute stage and is composed of three components: arousal, mode of response to stimuli, and content of consciousness<sup>12</sup>. At discharge, medical history was selected from pass items, and correlation coefficients were calculated.

For the total FIM score on discharge from convalescent hospitals, the following were selected from pass items: sex, age, outcome destination from convalescent hospitals, presence or absence of higher brain dysfunction (at discharge from an acute care hospital), presence or absence of dysphagia (at discharge from an acute care hospital), presence or absence of long-term care insurance (at discharge from an acute care hospital), and NIHSS score (at discharge from an acute care hospital). Correlation coefficients were then calculated. Sex, outcome destination, presence or absence of long-term care insurance, and the presence or absence of sequelae are nominal scales; therefore, analysis was performed using dummy variables. For both dependent variables, independent variables were selected, and  $|r| \geq 0.2$ .

### Multiple regression analysis

To extract factors affecting 1) length of stay in convalescent hospitals and 2) FIM score on discharge from convalescent hospitals, multiple regression analysis was performed using the stepwise method, with "length of stay in convalescent hospitals" and "total FIM score on discharge from convalescent hospitals" as dependent variables. Based on the correlation coefficient, variables with a strong correlation were selected as independent variables. A simple regression analysis was performed on the selected independent variables; however, no item had a corrected  $R^2$  of  $\geq 0.5$ , and no variables showed a significant correlation. The selection of independent variables for each model was as follows:

- 1) Length of stay in convalescent hospitals: age, outcome destination, total motor FIM score (at admission to a convalescent hospital), total cognitive FIM score (at admission to a convalescent hospital), NIHSS score (at discharge from an acute care hospital), JCS score (at discharge from an acute care hospital), and presence or absence of long-term care insurance (at discharge from an acute care hospital);
- 2) Total FIM score on discharge from convalescent hospitals: sex, outcome destination, age, NIHSS score (at discharge from an acute care hospital), presence or absence of long-term care insurance (at discharge from an acute care hospital), presence or absence of



dysphagia (at discharge from an acute care hospital), and presence or absence of higher brain dysfunction (at discharge from an acute care hospital).

Sex, outcome destination, presence or absence of long-term care insurance, and the presence or absence of sequelae are nominal scales; therefore, analysis was performed using dummy variables. Variables with  $|t| \geq 2$  and  $|\beta| \geq 0.2$ , assessed as having “some influence” on the dependent variable, were used as the criteria for the final selection of independent variables. After the analysis, a model with a degree-of-freedom-adjusted coefficient of determination ( $R^2$ ) of  $\geq 0.3$  and a variance inflation factor (VIF) of  $< 10$  was used to assess multicollinearity. SPSS version 27.0 for Windows (IBM SPSS, Inc. Armonk, NY, USA) was used for the analysis. Statistical significance was set at  $P < 0.05$ .

Ethical considerations

This study was approved by the Ethical Research Committee of the University of Occupational Environmental Health, Japan, and was conducted in accordance with the Declaration of Helsinki.

Results

A total of 10,873 patients were enrolled, of whom 7,487 (68.9%) and 5,441 (50.0%) patients in acute care and convalescent hospitals, respectively, participated in the Liaison Critical Pathway (Table 1). The incidence rates by sex were 53.4% for men and 46.6% for women, with a slightly higher incidence in men. The ages of stroke onset were 72.2

years in men and 77.4 years in women at acute care hospitals, whereas they were 71.9 years in men and 76.9 years in women at convalescent hospitals, with women tending to be older at the time of onset.

Cerebral infarction was the most common type of stroke. The mean lengths of hospital stay were 28.4 and 92.3 days in acute care and convalescent hospitals, respectively; however, the standard deviation (SD) of the latter was large, indicating a large variance.

The mean FIM scores were 67.1 on admission to a convalescent hospital and 87.4 at discharge. The mean FIM gain was 19.7; however, there was some variability (Table 2).

Regarding annual changes in the mean length of hospital stay in the acute care hospitals between 2009 and 2021, there was an increasing trend until 2012 but a decreasing trend after 2013 (Fig. 1). The mean length of stay in the convalescent hospitals remained approximately 90 days between 2009 and 2017. After peaking in 2015, it gradually shortened in 2016 and has since remained in the 80-day range. In 2021, it dropped significantly to 64.0 days; however, the data input may have been insufficient.

The majority (72%) of participants with mild stroke sustained a cerebral infarction, and the proportion of patients with cerebral hemorrhage increased with increasing disease severity (Table 2).

At discharge from the acute care hospitals, the mean length of hospital stay according to severity was 25.8 days in the mild group. Furthermore, the length of stay in convalescent hospitals was 75.6 days in the mild group, and the length of stay in both hospitals increased with stroke severity and was approximately 4 months in the severe group.

The total FIM scores on discharge from the convalescent hospitals were 103.3, 77.8, and 41.1 for the mild, moderate, and severe groups, respectively. The FIM gains were 19.3, 23.7, and 14.2 in the mild, moderate, and severe groups, respectively, with the highest FIM gain in the moderate group.

After discharge from acute care hospitals, 84% of patients were transferred to convalescent hospitals, whereas 65.5% of patients in convalescent hospitals were discharged home (Table 3).

The dependent variables were the length of hospital stay and FIM score on discharge from the convalescent hospitals, which were calculated using Spearman’s rank correlation coefficient (Table 4). A moderately negative correlation was observed between motor area FIM score (on admission to convalescent hospitals) and length of stay in convalescent hospitals. A weak positive correlation was observed among long-term care insurance facilities (recovery stage outcomes), NIHSS score (on admission to acute care hospital), and JCS score (on admission to acute care hospital). FIM score on discharge from convalescent hospitals showed a moderate positive correlation with discharge to home (outcome destination from the convalescent hospitals), no dysphagia (at

Table 1  
Characteristics of registered patients with stroke.

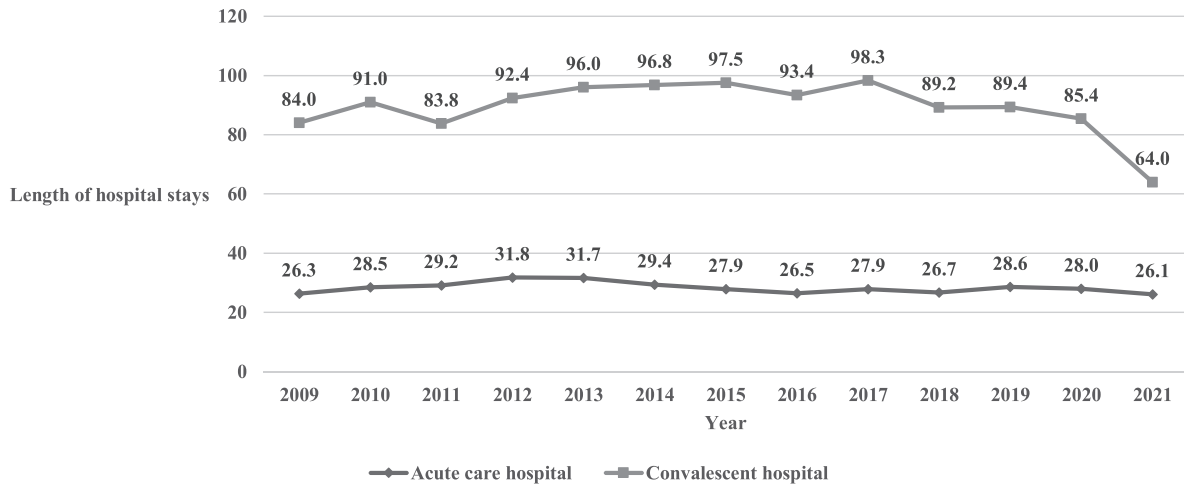
Acute care hospital (n=7,487)			Convalescent hospital (n=5,441)		
	Mean (SD)	Median (IQR)		Mean (SD)	Median (IQR)
Age (n, %), yrs.			Age (n, %), yrs.		
Total (n=7,472, 100)	74.6 (12.1)	76 (67–84)	Total (n=5,436, 100)	74.2 (12.1)	76 (67–83)
Male (n=3,989, 53.4)	72.2 (12.0)	74 (65–81)	Male (n=2,919, 53.7)	71.9 (12.1)	73 (65–81)
female (n=3,480, 46.6)	77.4 (11.5)	79 (70–86)	Female (n=2,515, 46.3)	76.9 (11.6)	79 (70–85)
known (n=3, 0.0)	-	-	Unknown (n=2, 0.0)	-	-
Stroke subtype (n, %), yrs.			Stroke subtype (n, %), yrs.		
IS (4,841, 64.8)	76.7 (10.9)	78 (70–85)	IS (3,538, 65.0)	76.4 (11.0)	79 (70–84)
ICH (2,196, 29.4)	70.9 (12.8)	72 (63–80)	ICH (1,614, 29.7)	70.4 (12.8)	71 (63–80)
SAH (322, 4.3)	68.5 (14.0)	71 (60–80)	SAH (239, 4.4)	67.0 (14.4)	67 (57–78)
Others (20, 0.3)	-	-	Others (13, 0.2)	-	-
Unknown (108, 1.4)	-	-	Unknown (37, 0.7)	-	-
Length of hospital stay, days	28.4 (24.2)	24 (18–34)	Length of hospital stay, days		83 (47–131)
			FIM score in Convalescent Hospital (n)		
			Admission (3,872)	67.1 (33.0)	68 (36–95)
			Discharge (4,735)	87.4 (35.5)	101 (59–118)
			FIM gain (n=3,843)	19.7 (19.0)	16 (5–31)

IS: Ischemic Stroke, ICH: Intracerebral hemorrhage, SAH: Subarachnoid hemorrhage, FIM: Functional Independence Measure; SD: Standard Deviation, IQR: Interquartile Range

Table 2  
Patients’ characteristics according to stroke severity.

	Mild (n=3,673)	Moderate (n=1,827)	Severe (n=947)
Stroke subtype			
IS	72.4%	61.1%	53.6%
ICH	23.3%	36.0%	41.0%
SAH	4.3%	3.0%	5.4%
Hospital stay (Mean (SD)/Median (IQR)), days			
Acute care hospital	25.8 (15.7) / 22 (17–31)	29.8 (30.5) / 26 (19–35)	35.4 (17.2) / 32 (23–45)
Convalescent hospital	75.6 (52.1) / 67 (39–105)	111.6 (72.7) / 111 (71–148)	125.5 (116.7) / 119 (70–159)
FIM score in Convalescent hospital (Mean (SD) / Median (IQR))			
Discharge	103.3 (25.3) / 113 (93–122)	77.8 (33.5) / 81 (48–109)	41.1 (28.0) / 29 (20–53.75)
FIM gain	19.3 (17.7) / 17 (6–31)	23.7 (19.9) / 22 (8–37)	14.2 (20.6) / 4 (0–20)

IS: Ischemic Stroke, ICH: Intracerebral hemorrhage, SAH: Subarachnoid hemorrhage, FIM: Functional Independence Measure; IQR: Interquartile Range, SD: standard deviation



**Fig. 1.** Annual trend of length of hospital stay

The figure illustrates the annual trends in the length of hospital stay in acute care hospitals and in convalescent hospitals.

**Table 3**

Destination from Acute care/Convalescent hospital.

Acute care hospital (n=7,371)		Convalescent hospital (n=5,157)	
	%		%
Convalescent hospital	84.0	Discharge to home	66.3
Community based care unit	10.0	Medical and nursing care sanatoria	9.2
Discharge to home	3.0	Return to admission for acute care hospital	8.5
Recuperation hospitals	1.1	General Hospital	5.9
Medical and nursing care sanatoria	0.3	Recuperation hospitals	4.8
Others	1.5	Death	1.4
		Others	4.8

**Table 4**

Spearman's rank correlation coefficient of the length of stay in the convalescent hospital and total FIM score.

Correlation coefficient of length of stay in the convalescent hospital		Correlation coefficient of total FIM score (at discharge from convalescent hospital)	
NIHSS in acute care hospital	0.37**	Discharge to home from convalescent hospital	0.62**
Long-term care health facilities	0.23**	No dysphagia in acute care hospital	0.46**
JCS in acute care hospital	0.23**	No long-term care insurance in acute care hospital	0.42**
Cognitive FIM on admission to convalescent hospital	-0.29**	No higher brain dysfunction in acute care hospital	0.42**
Motor FIM on admission to convalescent hospital	-0.44**	Long-term care health facilities from rehabilitation hospital	-0.25**
		Age	-0.44**
		NIHSS in acute care hospital	-0.57**

NIHSS: National Institutes of Health Stroke Scale, FIM: Functional Independence Measure, mRS: modify Rankin Scale, JCS: Japan Coma Scale; other abbreviations are same as in Table 1

\*\* P<0.001

discharge from acute care hospitals), and no higher brain dysfunction (at discharge from acute care hospitals). A moderate negative correlation was observed among age, JCS score (at discharge from acute care hospitals), and NIHSS score (at discharge from acute care hospitals) (Table 4).

Multiple regression analysis was performed using the stepwise method.

1) For the length of stay in convalescent hospitals, the adjusted coefficient of determination ( $R^2$ ) was 0.15, and motor area FIM score (on admission to convalescent hospitals) was selected as the independent variable (Table 5). The standard partial regression coefficient was -0.37, indicating a negative relationship and that a high motor area FIM score was associated with a shorter hospital stay.

For the total FIM score on discharge from convalescent hospitals,  $R^2$  was 0.70, and the independent variables were discharge to home (outcome destination from the convalescent hospitals) and NIHSS score (at discharge from acute care hospitals) (Table 6). The standard partial regression coefficient had a positive relationship with discharge to home at 0.37 and a negative relationship with NIHSS score (at discharge from the acute care hospitals) at -0.34, indicating an association with the dependent variable. The total FIM score on discharge from the convalescent hospitals was higher among patients discharged to home, and increased stroke severity on discharge from the acute care hospitals was associated with a lower total FIM score on discharge from the convalescent hospitals.

## Discussion

### Overview

Over 10,000 people were registered in the Kitakyushu Stroke Liaison Critical Pathway, which provides community-based medical care supporting patients with stroke throughout the region, targeting Kitakyushu City and its surrounding areas.

The mean length of hospital stay was approximately 1 month in acute care hospitals and 3 months in convalescent hospitals, with a decreasing annual trend for both types of hospitals in recent years.

Stroke severity was associated with a higher incidence of cerebral hemorrhage, longer mean length of stay in acute care and convalescent hospitals, and lower total FIM score on discharge from convalescent hospitals, whereas FIM gain was highest in patients with moderate

**Table 5**

Stepwise multiple regression analysis of length of stay in the convalescent hospital (n=3,392).

Variable	B (95% CI)	$\beta$	t-score	P-Value
Motor FIM	-1.09 (-1.22 to -0.95)	-0.37	-15.71	<0.001

$R^2$ : 0.15, F score: 84.36

B: partial regression coefficient,  $\beta$ : standardized partial regression coefficient, CI: Confidence Interval; FIM: Functional Independence Measure

**Table 6**

Stepwise multiple regression analyses of FIM score on discharge from convalescent hospital (n=3,785).

Variable	B (95%CI)	$\beta$	t-score	P-Value
Discharge to home from convalescent hospital	28.23 (26.53 to 29.92)	0.37	32.62	<0.001
NIHSS in acute care hospital	-1.89 (-2.02 to -1.76)	-0.34	-28.73	<0.001

R<sup>2</sup>: 0.70, F score: 1230.86

NIHSS: National Institutes of Health Stroke Scale, FIM: Functional Independence Measure

disease.

Furthermore, >80% of patients in acute care hospitals were transferred to a convalescent hospital, and approximately 70% of those in convalescent hospitals were discharged home, whereas 10% were discharged to a healthcare facility for older adults.

#### Age at onset

The mean ages at the time of stroke onset were 74.6 and 71.3 years for patients enrolled in this pass and those in other areas, with slightly older age of onset compared with patients in another prefecture<sup>13</sup>. As for other countries, the mean age at stroke onset is 63.5 years in China<sup>14</sup>, 71.4 years in Finland<sup>15</sup>, 75.0 years in the Evros province in northeastern Greece<sup>16</sup>, and 71.6 years in the Ludwigshafen region of Germany<sup>17</sup>. The current study's results show an older age of onset than studies conducted in other Asian regions or countries; however, there was no difference when comparing our findings with those of studies performed in European areas<sup>18</sup>.

In the present study, the age at stroke onset was higher among women than among men, and in 2008–2017, the ages of onset were 71.4 years for men and 77.8 years for women<sup>19</sup>, consistent with data from the European Union<sup>16, 18</sup>.

The median ages of onset were 78 years for cerebral infarction, 72 years for cerebral hemorrhage, and 71 years for subarachnoid hemorrhage; thus, median age of onset was higher for all stroke types in the present study than in studies from other regions of Japan<sup>13, 20</sup>. Nationwide, the median age of onset is 74 years for cerebral infarction, 70 years for cerebral hemorrhage, and 64 years for subarachnoid hemorrhage<sup>21</sup>, suggesting that the median age of onset in the Kitakyushu region, which is the subject of this study, is relatively high.

Kyoto City, another region in Japan, has a population of approximately 1.4 million and an aging rate of 28.5%<sup>6, 13</sup>, whereas Kitakyushu City has a population of approximately 0.93 million and an aging rate of 31.2%<sup>6</sup>. Compared with Kyoto City, Kitakyushu City has the highest aging rate among ordinance-designated cities<sup>6</sup>; therefore, the age at onset tends to be high in terms of sex and stroke type.

#### Sex

The incidence of all stroke subtypes was slightly higher among men, and there was no significant difference between the present study's data and nationwide data or data from other regions in Japan during 1988–2019<sup>13, 21, 22</sup>. Male sex is a risk factor for stroke, with a higher stroke incidence observed among men in the present study. However, the average life expectancy is higher among women, and depending on changes in the composition of the older adult population, the stroke incidence among women may increase in the future.

#### Subtype

In Kitakyushu City, according to The Japan Stroke Data Bank, cerebral infarction, cerebral hemorrhage, and subarachnoid hemorrhage accounted for 73.9%, 19.7%, and 6.4% of cases, respectively<sup>21</sup>. According to a study in Hisayama, a city in the same prefecture as Kitakyushu City, the rate of first-onset cerebral hemorrhage remained constant at 16–20% between 1961 and 2012<sup>23</sup>. It can be said that the

rate of cerebral hemorrhage tended to be higher in the Kitakyushu region (29.1%) than in other regions and compared with the national data, although the rates of cerebral infarction and subarachnoid hemorrhage were consistent with the national data. According to a standardized international case-control study of 32 countries across Asia, America, and Europe, the incidence of cerebral hemorrhage tended to be higher in China (27.6%) and Southeast Asia (33.3%) than in Western countries (6.7%–8.4%)<sup>24</sup>. The incidence of intracerebral hemorrhage in Asian countries is higher than that in Western countries and twice as high as that in other races, such as Hispanics and African-Americans, increasing with age<sup>25, 26</sup>. Due to the aging of the population in the Kitakyushu area, it may reflect the characteristics unique to Asians.

High salt intake has been shown to increase the risk of stroke<sup>27–29</sup>. Therefore, high salt intake may affect the onset of a cerebral hemorrhage.

The incidence of cerebral infarction decreased with increasing stroke severity, whereas the incidence of cerebral hemorrhage increased with increasing stroke severity. The risk of developing stroke increases with age, and poor prognostic factors include advanced age, the presence of a large hematoma, hematoma expansion, intraventricular hemorrhage, and hemorrhage at the base of the brain<sup>30, 31</sup>. It is expected that Kitakyushu City has a large older population and that patients with comorbidities experienced recurrent stroke or new onset of cerebral hemorrhage. Thus, it was suggested that an increase in age at onset was associated with an increased incidence of severe cerebral hemorrhage.

#### Length of hospital stay

The mean length of stay in acute care hospitals in the present study was 28.4 days. Data from a previous study in Japan from 2014 showed a slight decrease, to 29.5 days<sup>32</sup>. Compared with the mean length of stay in acute care hospitals in other countries such as China (17.8 days)<sup>24</sup> and Finland (17.2 days)<sup>15</sup>, the length of stay in acute care hospitals for pass holders tended to be slightly longer. The type of medical insurance and daily living functions at the time of hospitalization are factors that prolong the length of hospital stay<sup>33</sup>, and it is conceivable that the support provided by medical insurance and the decline in daily living functions affected the length of hospital stay. In particular, because of Japan's universal health insurance system, the out-of-pocket burden of medical expenses is low, affecting the duration of hospitalization. In addition, due to many comorbidities resulting from advanced age, it takes several days for patients to stabilize, and after adequate acute phase rehabilitation and setting the treatment policy, the patient is transferred to a convalescent hospital. Besides the influence of the medical system, another factor contributing to the prolonged hospitalization in the Kitakyushu area is the availability of a conducive environment for convalescent hospitals to focus on functional recovery by admitting patients from acute care hospitals after achieving stable medical conditions.

According to national data in 2017, the mean hospital stay for cerebrovascular disease by age group was 78.2 days overall; however, the mean hospital stays were 86.7 days for those aged ≥65 years and 98.9 days for those aged ≥75 years<sup>34</sup>. In addition, national data in 2020 showed that medical costs for those aged ≥65 years accounted for 61.5% of the total, and the aging population has led to the increase in the average length of hospital stay<sup>35</sup>. The hospital length of stay was extended due to the aging of the population and the use of national health insurance.

The mean length of stay in convalescent hospitals was 92.0 days in the present study and 93.6 days in Japan as a whole. Therefore, the difference was minimal<sup>36, 37</sup>.

The mean length of hospital stay according to severity showed a trend toward longer stays in both acute care and convalescent hospitals (Table 2), consistent with the literature<sup>38</sup> and the Korean registry data<sup>39</sup>. Age, FIM gain, and total FIM scores in the areas of exercise, mobility, communication, and self-care at the time of admission are predictors

known to affect the length of stay in convalescent hospitals<sup>11</sup>. These data weakly correlated with daily living function (Table 4), and multiple regression analysis also indicated motor area FIM as an associated factor (Table 5). In addition, medical complications may prolong the length of hospital stay. For example, pneumonia and urinary tract infections are factors known to prolong the length of stay in acute care hospitals<sup>40</sup>.

The mean length of stay in convalescent hospitals tended to increase for severe diseases compared with that for moderate diseases (Table 2). With increased disease severity, the patient's general condition may not stabilize, requiring further medical resources, and adjustment to the destination may be necessary, potentially extending the duration of hospitalization. The annual changes in the mean length of hospital stay tended to diminish over time in both acute care and convalescent hospitals (Fig. 1). According to data from other prefectures in Japan, the median length of stay in acute care hospitals decreased from 18 to 12 days between 2009 and 2016. Similarly, the length of stay in convalescent hospitals decreased from 104 days in 2009 to 60 days in 2016, with a trend of shortening stay with increasing age. The Kitakyushu area showed a similar diminishing trend, although slowly<sup>38</sup>. These results are consistent with those of the present study.

### Outcome destinations

Approximately 80% of the patients were transferred from acute care hospitals to convalescent hospitals, and two-thirds of patients in convalescent hospitals were discharged home (Table 3). The reason why many patients are transferred from acute care hospitals to convalescent hospitals is largely associated with the Japanese medical system based on the functional differentiation of hospitals that mainly provide acute care after stroke onset, followed by transfer to convalescent hospitals for rehabilitation.

The prevalence of patients that returned to acute care hospitals from convalescent hospitals was 8.5%. Recurrent stroke, deterioration of underlying diseases, and complications in convalescent hospitals may lead to rehospitalization. Therefore, management of the general condition in a convalescent hospital is important. Approximately 10% of patients transitioned from the convalescent hospitals to long-term care. If patients are older and their NIHSS score is severe, they are discharged to a long-term care facility<sup>41</sup>. The proportion of patients discharged to nursing homes increases as the population ages. Additionally, a previous study reported that patients with NIHSS scores of  $\geq 13$  are discharged to long-term care facilities and that a 1-point increase in the NIHSS score significantly decreases discharge to home. Thus, there is an association between discharge destination and stroke severity<sup>9</sup>. Discharge to home is associated with a mild disability after rehabilitation treatment and requires good family and community support<sup>42</sup>. Rehabilitation at convalescent hospitals, nursing care at home, and the effective use of social resource services are important for discharge to home. A study of outcome destinations revealed that predicting disease severity is somewhat possible. Patients with an FIM score  $\leq 39$  and NIHSS score  $\geq 14$  were 3.4 times more likely to be discharged to a facility, whereas those with an FIM score  $\geq 80$  and NIHSS score  $\leq 5$  were 12 times more likely to be discharged home<sup>43</sup>. Therefore, the higher the degree of functional independence and the lower the severity, the higher the possibility of discharge to home. However, it has been reported that rehabilitation intervention in the subacute phase did not reduce the need for long-term nursing care<sup>44</sup>, and even if patients' physical function is restored, those with severe conditions require nursing care. Therefore, we consider that cooperation with the community and the use of social resources is important.

### FIM score on discharge and FIM gain

The total FIM score on discharge from convalescent hospitals was inversely correlated with stroke severity (Table 2). Because the degree of independence before admission to a convalescent hospital determines

the direction of physical functionality after discharge<sup>45</sup>, it is important to determine the degree of residual function at the time of discharge from an acute care hospital. Therefore, improving the functional level at the time of discharge from an acute care hospital is important, and early treatment and rehabilitation after the onset of stroke are essential.

FIM score on discharge from convalescent hospitals and daily living functions at acute care hospitals tend to decline with age.

Regarding FIM gain, it tended to be highest in cases of moderately severe stroke. FIM gain tended to be highest in patients with moderate FIM scores of 41–80 on admission to a convalescent hospital<sup>46</sup>. The effect of rehabilitation treatment is greater in patients with moderate stroke than in those with mild or severe stroke.

### Limitations

First, not all hospitals in the Kitakyushu area are enrolled in the pass program, and not all patients with stroke in the Kitakyushu area were included. Certain hospitals in the Kitakyushu region have varying systems that may lead to increased workload and discrepancies. Therefore, standardizing the data across hospitals is necessary to correct such differences and improve the overall quality of care. A study linking stroke registration and health insurance data in South Korea<sup>47</sup> and another study on the usefulness of stroke registration using the diagnosis procedure combination/per-diem payment system in Japan were conducted in Iwate Prefecture<sup>48</sup>. Linking medical data, health insurance, and pass data will promote the pass use and cooperation with regional authorities delivering medical care, thus improving the quality of care for patients with stroke. It is necessary to improve the availability of the pass to promote its use in the local community. We believe increasing the number of hospitals participating in the pass scheme is important to adequately capture the current stroke trends across the Kitakyushu region.

Second, there were items with missing data. This may be explained by difficulties in data input at the medical site, such as a busy schedule, thus raising the possibility of information bias. Specifically, there were many missing values in the data input after discharge from convalescent hospitals. However, a comprehensive analysis at the regional level requires data from the acute stage through to the chronic stage. Digitizing the pass would increase information sharing between hospitals, reduce the burden of input work at clinical sites, and allow timely input to minimize missing values.

Third, compared with studies in other regions, our study did not adjust the population composition ratio by age group; therefore, we need to examine this in the future. However, by comparing the results of the present study with those of studies from other regions in Japan, we consider that it will be possible to understand the regional characteristics of patients with stroke and provide useful data in formulating strategies for improving the quality of stroke treatment tailored to regional characteristics.

### Conclusion

Based on the data of the Kitakyushu Stroke Regional Collaboration pass, we investigated subtype rates, clinical features, outcomes, and daily living functions among patients with stroke in the Kitakyushu area and examined the patients' characteristics. In the Kitakyushu region, the age at stroke onset and incidence of cerebral hemorrhage were high. The length of hospital stay tended to increase with increasing stroke severity in both acute care and convalescent hospitals. FIM gain was highest in moderately ill patients, suggesting that the effect of rehabilitation on moderately ill patients is beneficial.

### Funding

None.



## Grant support

None.

## CRedit authorship contribution statement

**Yukihiro Shimozuru:** Writing – original draft. **Yasuyuki Matsushima:** Data curation, Writing – review & editing. **Mitsuhiro Ochi:** Data curation, Writing – review & editing. **Hideaki Itoh:** Data curation, Writing – review & editing. **Akiko Hachisuka:** Data curation, Writing – review & editing. **Satoru Saeki:** Supervision, Writing – review & editing.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgment

The authors thank the Kitakyushu City Health and Welfare Bureau, the Kitakyushu City Medical Association, and the Department of Rehabilitation Medicine at the University of Occupational and Environmental Medicine for the data, as well as the clerical staff for their help in organizing the data.

We also thank Editage (<https://www.editage.com/>) for editing and reviewing this manuscript for English language.

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## CASE REPORT

# Perioperative Rehabilitation in Collaboration with the Department of Occupational Medicine for Patients with Cholangiocarcinoma: A Case Report

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**ABSTRACT. Introduction:** Although the number of cancer survivors has increased, the role of physical therapy in return to work (RTW) for employed patients with cancer remains unclear. **Case presentation:** The patient is a 50-year-old man diagnosed with cholangiocarcinoma who worked as a liquefied petroleum gas station filler. He started perioperative rehabilitation and underwent pancreaticoduodenectomy for cholangiocarcinoma. He developed a postoperative pancreatic fistula, which improved with conservative treatment over 40 days. Although he achieved independence regarding day-to-day activities, his physical condition and workability worsened, as his skeletal muscle index decreased from 8.7 to 7.7, 6-min walk distance from 518 to 460 m, and work ability index (WAI) from 37 to 20 points. His physical therapist was concerned about his RTW and recommended that he receive RTW support from the Department of Occupational Medicine (DOM). The DOM employed a team approach for the RTW strategy, and the primary physician, occupational physician, and company collaborated to support the patient. After the outpatient treatment protocol and RTW support plans were formulated, the patient was discharged. The physical therapist reported declining physical performance and WAI at the DOM's multidisciplinary conference. After consulting with multiple professionals, the team recommended work resumption in stages: part-time for three months and full-time for four months after surgery while undergoing oral adjuvant chemotherapy. The WAI improved to 35 points after RTW. **Conclusion:** This case report suggests that physical therapists are vital in providing continuous patient support, from perioperative rehabilitation to DOM intervention, to build physical strength for return to work.

**Key words:** Cholangiocarcinoma, Perioperative rehabilitation, Department of Occupational Medicine, Return to work

(Phys Ther Res 00: 00–00, 0000)

## Introduction

According to the World Health Organization (WHO), one in five persons will develop cancer in their lifetime<sup>1)</sup>. Early cancer detection and development of treatment techniques have improved life expectancy and increased the number of cancer survivors, with approximately half of cancer survivors estimated to be employed<sup>2)</sup>. For cancer survivors, a worsening employment environment, including layoffs, reduces their quality of life and leads to socio-economic losses<sup>3,4)</sup>. In addition, Japan is an aging society with a declining birthrate, and by 2040, the proportion of the working-age population

Received: November 1, 2023

Accepted: March 1, 2024

Advance Publication by J-STAGE: April 23, 2024

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doi: 10.1298/ptr.E10275



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(15–64 years old) is expected to decrease further<sup>5</sup>. As a countermeasure to the anticipated increase in social security costs, the Japanese government has implemented certain measures to help cancer survivors return to work (RTW) as one of its primary policies<sup>6</sup>. Therefore, employment support is crucial for cancer survivors.

Gastrointestinal cancer is highly prevalent, and pancreaticoduodenectomy is one of the most challenging surgical procedures for cholangiocarcinoma. Recent advances in surgical techniques and perioperative management have reduced the surgery-related mortality rate of pancreaticoduodenectomy; however, the incidence of postoperative complications remains extremely high<sup>7</sup>. Postoperative complications are a disincentive to resume work<sup>8</sup>.

In a systematic review, perioperative respiratory physical therapy was reported to be effective in preventing postoperative complications of thoracoabdominal surgery and is widely practiced in Japan<sup>9</sup>. However, the Japanese medical system does not approve outpatient rehabilitation for cancer patients, making it difficult for the patients to obtain rehabilitation support, including RTW assistance, after discharge.

In Japan, from 2018, it became possible to calculate medical payments when medical institutions provide employment support to cancer patients<sup>10</sup>. In 2018, the Department of Occupational Medicine (DOM) was established at our hospital to provide the patients with health and employment support<sup>11</sup>. The DOM comprises a multidisciplinary team (physicians, rehabilitation staff, nurses, medical social workers, etc.) of qualified health and employment support coordinators. Nevertheless, the role of physical therapy in RTW for employed patients with cancer remains unclear.

Herein, we aim to clarify the role of physical therapy in the process of RTW for cancer patients based on our experience with a case of perioperative rehabilitation in collaboration with the DOM in a patient with cholangiocarcinoma.

## Case Presentation

### *Patient*

The patient is a 50-year-old man (height: 172 cm, weight: 74.0 kg, body mass index: 25.0 kg/m<sup>2</sup>). Two months ago, he had no symptoms other than jaundice and was diagnosed with distal cholangiocarcinoma at another hospital. He was subsequently admitted to our hospital for surgery. Laboratory tests showed increased aspartate aminotransferase (AST), alanine aminotransferase (ALT), and total bilirubin levels (AST: 34 IU/L, ALT: 63 IU/L and total bilirubin 2.4 mg/dL). Computed tomography (CT) revealed dilatation of the biliary tree and thickening of the common bile duct wall but no findings suggestive of metastasis. Endoscopic retrograde cholangiography (ERC) showed stenosis of the distal portion of the common bile duct. A biopsy of the distal bile duct showed adenocarcinoma cells. Based on these results, we diagnosed the patient with distal cholangiocarcinoma

with clinical stage IIB (cT3N0M0) using the 7th edition of the Japanese classification of biliary tract cancers. The patient worked as a liquefied petroleum gas (LPG) station filler for 30 years. The patient had to return to work following surgery. The company has 480 employees, including a part-time occupational physician, occupational health nurse, and health supervisor, with eight employees at their branch office. Two work shifts (8:00–17:00 hours and 11:00–20:00 hours) are used. His work involved holding hoses and connectors and filling LPG vehicles with gas, which has an estimated metabolic equivalent (MET) value of 3.0<sup>12</sup>. During busy periods, gas-filling work sometimes continued for over two hours without rest. He commuted for 30 min on foot and 15 min on the subway. As he was performing his daily life and work with no difficulties, he did not feel the need for DOM support and declined assistance during the preoperative interview.

### *Preoperative physical therapy intervention*

Upon admission, the patient was prescribed preoperative physical therapy to prepare his physical condition for surgery. Preoperative training, comprising five 60-min sessions per week for two weeks, was conducted in the rehabilitation room. The training consisted of breathing exercises, strength training, endurance training using a bicycle ergometer, and self-training guidance (Table 1). For preoperative physical performance assessment, the skeletal muscle index, knee extension strength, grip strength, 6-min walk distance, and Barthel index were measured. The skeletal muscle index was calculated using a body composition meter (InBody S-10; InBody Japan, Tokyo, Japan). Knee extension and grip strength were used to assess muscle strength. A handheld dynamometer ( $\mu$ Tas MT-1; ANIMA, Tokyo, Japan) was used to measure the knee extension muscle strength. A Jamar-type hydraulic grip dynamometer (SH5001; SAKAI Medical, Tokyo, Japan) was used to measure grip strength. Details of the physical performance assessment were described in previous reports<sup>13,14</sup>. The results of the physical performance assessments are presented in Table 2. The patient's preoperative physical performance was favorable. The work ability index (WAI) was assessed to determine his work ability before surgery, which was rated as "good." (Table 3).

### *Postoperative course*

Fourteen days after admission, the patient underwent planned pancreaticoduodenectomy with portal vein resection for cholangiocarcinoma. Postoperative physical therapy was initiated on the day after surgery. Early mobilization progressed in stages, starting with wheelchair transfers, then 50 m, 100 m, and 200 m walks in the ward (Table 1).

However, on postoperative day (POD) 5, the patient developed a pancreatic fistula with fever, and open drainage was performed. The patient was forced to rest, and postoperative physical therapy was performed at the bedside according to his physical condition. On POD 15, the fever

**Table 1.** Physical therapy program

Preoperative periods (two weeks)	
Five sessions/week, 60-min/session, in gymnasiums	
Breathing exercise	Coughing, huffing, abdominal breathing exercises
Strength training	Squats, calf raises (100 repetitions)
Endurance training	Moderate intensity cycle ergometer (20–30 min)
Self-training guidance	Necessity and methods of early postoperative weaning Physical activity (at least 10,000 steps per day)
Postoperative periods (POD 1–4)	
Five sessions/week, 20-min/session, early mobilization in the ward	
POD 1	Wheelchair transfers
POD 2	50 m walks
POD 3	100 m walks
POD 4	200 m walks
Postoperative complication period (POD 5–14)	
Five sessions/week, 20-min/session, at the bedside, under sustained drainage	
Conditioning	Stretching, massage
Mobilization	Toilet walk—200 m walk, depending on physical condition
Sustained drainage periods (POD 15–42)	
Five sessions/week, 40-min/session, in gymnasiums, under sustained drainage	
Resistance training	Squats, calf raises (30–100 repetitions)
Endurance training	Light-to-moderate intensity interval cycle ergometer (10–20 min) 200–500 m walks
Self-training guidance	Physical activity (at least 5,000 steps per day)
Drain removal—discharge period (POD 43)	
Self-training guidance	Squats, calf raises (100 repetitions) Physical activity (at least 10,000 steps per day) Maintain the activities of daily life and prepare to resume work

POD, postoperative day

improved, and he started gymnasium rehabilitation with limb strength and endurance training in a light-load interval format under sustained drainage. However, residual fatigue rendered active exercise difficult (Table 1).

As a result, his skeletal mass index decreased from 8.7 to 7.7 kg/m<sup>2</sup>, the 6-min walking distance declined from 518 to 460 m (predicted reduction of METs from 3.89 to 3.55)<sup>15)</sup>, and his WAI summary score was reduced from 37 to

**Table 2.** Changes in physical performance parameters during hospitalization

	Preoperative	Discharge
BW (kg)	74.0	68.7
Skeletal muscle index (kg/m <sup>2</sup> )	8.7	7.7
Knee extension strength (kgf/BW)	0.51/ 0.49	0.60/0.47
Grip strength (kg) (Rt./Lt.)	32/32	34/36
6-min walk distance (m) (Rt./Lt.)	518	460
Barthel index (pts)	100	100

BW, body weight; Rt., right; Lt., left; pts, points

20 points) before discharge (Table 2). The patient began to express intense anxiety due to fatigue and weakness during physical therapy. The patient said, “I feel that my physical strength is weakening. I am so exhausted even in my daily life and worried about returning to work.” His physical therapist reported that his physical condition was sufficient for day-to-day activities but not for working. Therefore, the physical therapist recommended a self-training program at the time of discharge, including 1) muscle strengthening training with squats and calf raises with 100 repetitions, 2) physical activity (at least 10000 steps per day<sup>16)</sup>), and 3) maintaining the activities of daily life and preparing to resume work (Table 1). Furthermore, the physical therapist recommended a DOM intervention for the patient. The patient accepted the DOM intervention, which was initiated.

#### DOM intervention

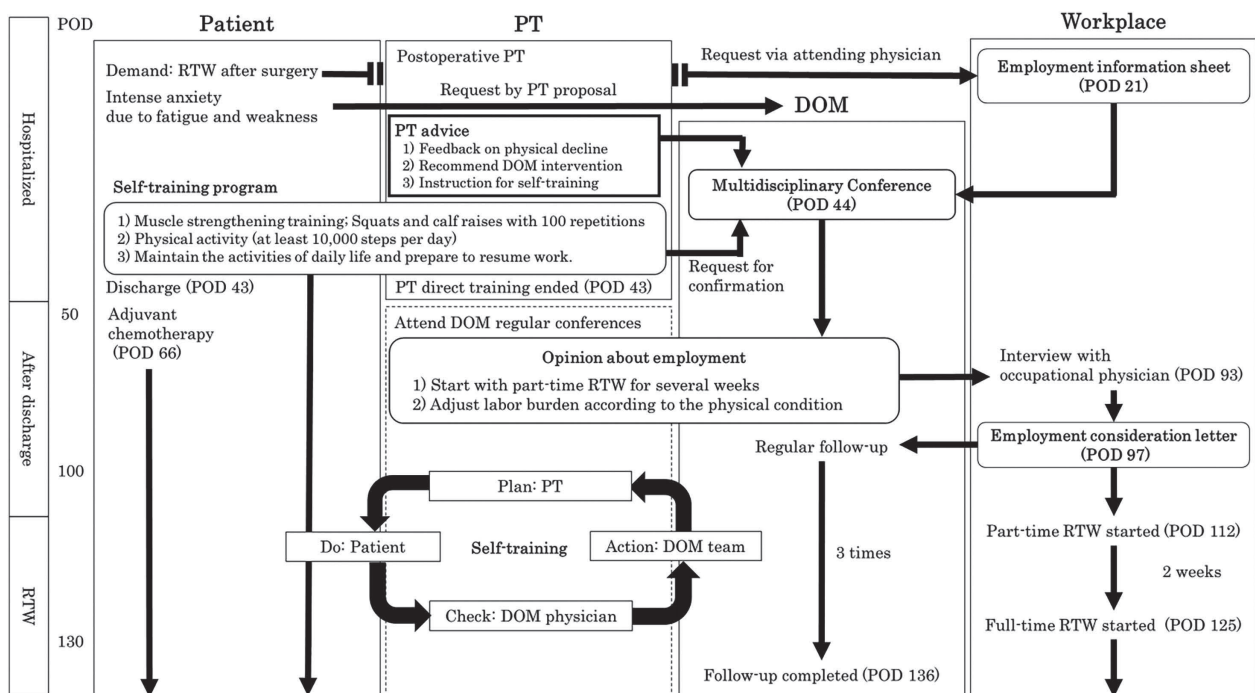
The patient was discharged on POD 43. Since outpatient rehabilitation for cancer patients is not approved by the medical system in Japan; hence, at discharge, the patient was instructed to perform the following at home: 1) continue the resistance training that was performed during hospitalization, 2) carry a pedometer and aim to complete at least 10000 steps per day<sup>16)</sup>, and 3) maintain the activities of daily life and prepare to resume work.

The flow diagram from discharge to RTW is shown in Figure 1. Before surgery, the patient requested that his attending physician issue an opinion letter to facilitate the RTW. Therefore, the attending physician requested employment information from the workplace, and on POD 21, an employment information sheet was provided by the employer. The employment information sheet stated that the RTW requirements were the ability to 1) commute to work independently using public transportation and 2) communicate and work outdoors using the hands and feet. On POD 44, the DOM convened a multidisciplinary conference. At the meeting, the physical therapist reported that the patient’s physical performance and work ability decreased after surgery but that he could resume work physically, with a reduced workload, given that the estimated METs value for the job was 3.0. In addition, the physical therapist requested that DOM team members check the implementation of the patient’s self-training

**Table 3.** Change in work ability index from hospitalization to return to work

S. No.	WAI dimensions	Preoperative	Discharge	After RTW
1	Subjective estimation of present work ability compared with lifetime best	8	1	7
2	Subjective work ability in relation to both the physical and mental demands of work	7	2	6
3	Number of diagnosed diseases	4	4	3
4	Subjective estimation of work impairment due to diseases	6	4	7
5	Sickness absenteeism during the past year	2	2	2
6	Own prognosis of work ability after 2 years	7	4	7
7	Enjoying daily tasks; active and alert; full hope for the future	3	3	3
	WAI summary score	37	20	35

WAI, work ability index; RTW, return to work

**Fig. 1.** Flow diagram from discharge to RTW

RTW, return to work; DOM, department of occupational medicine; POD, postoperative day; PT, physical therapy; ADL, activity of daily living

program during regular visits to the DOM. At the regular DOM clinic, the patient said “I have been able to continue the self-training program without any problems.” while showing his pedometer, and the DOM team shared the training progress at regular DOM meetings.

The attending physician reported that adjuvant chemotherapy was scheduled. After consulting with multiple professionals, it was determined that the patient could perform the work from a medical perspective. In addition, the DOM recommended the following reasonable accommodations for RTW: 1) starting with reduced working hours, mainly in the morning, for several weeks after RTW, and 2) adjusting labor burden according to the physical condition. Our decision is reflected in a letter of opinion regarding employment. The patient said, “I am grateful for DOM’s continuous support. I am anxious about the side effects now

that chemotherapy is starting, but I will do my best in the self-training program to get back to work.”

#### Progress after DOM intervention

On POD 66, oral fluoropyrimidines (S-1) was initiated as adjuvant chemotherapy. After S-1 administration, the patient did not experience any noticeable side effects. Based on the letter of opinion regarding employment, the occupational physician interviewed the patient on POD 93. During the interview, the following employment considerations were determined: 1) to start with short morning-only shifts and transition to full RTW over three weeks and 2) to take a break indoors every hour during hot weather. On POD 97, an employment consideration letter was submitted to the workplace. Three regular medical examinations were conducted by the DOM until the patient resumed work, and lifestyle and



exercise habits were reviewed in preparation for his RTW. The patient said, “My return to work is getting closer, but I am vaguely worried about whether I will be able to do it. Anyway, I will not know until I try so that I will do my best.”

On POD 112, the patient resumed the morning shift, which was expanded to 6 h, one week later. One week after starting the reduced working hours (POD 125), the patient completely resumed regular work without overtime. After confirming that there would be no issues with continuing to work after his RTW, the patient completed the DOM assessment on POD 136. All WAI items and summary scores that decreased after surgery improved after RTW (Table 3). The patient said, “Thanks to DOM’s outreach to my workplace and the occupational physician, I was able to return to work with peace of mind. Fortunately, my boss and colleagues also supported me a lot.”

## Discussion

In this case, we performed perioperative rehabilitation in collaboration with the DOM in a patient with cholangiocarcinoma, and two crucial clinical findings were obtained. First, perioperative rehabilitation in collaboration with the DOM may be effective in facilitating a smooth RTW in patients with reduced exercise capacity and work ability following surgery. Second, physical therapists should actively promote health and employment support.

In this patient with cancer, who experienced reduced exercise capacity and work ability after surgery, incorporating an exercise component into the RTW support may have facilitated the seamless transition of exercise instruction from inpatient to outpatient treatment and enabled a smooth RTW. Pancreaticoduodenectomy has a high risk of postoperative complications, particularly pancreatic fistulas, which require long-term drainage<sup>2</sup>. A previous study reported postoperative complications as factors preventing RTW in cancer patients<sup>8</sup>. This patient also required prolonged drainage for 41 days and showed decreased weight, skeletal muscle mass, exercise capacity, and work ability. In addition, because the medical system does not approve outpatient rehabilitation for patients with cancer, physical therapy ended after the patient was provided with the instructions for self-training exercises. It has been reported that aerobic and resistance training-driven exercise interventions for working patients with cancer provide a higher RTW effect than usual care, thereby increasing awareness regarding the importance of rehabilitation interventions<sup>17</sup>. However, unlike rehabilitation programs for stroke and other diseases, outpatient rehabilitation after abdominal surgery is not well-established in clinical settings<sup>18</sup>. Comprehensive physical, psychological, and occupational interventions are reportedly effective in aiding RTW in breast cancer survivors<sup>19</sup>.

The physical therapist plays a crucial role in providing perioperative rehabilitation and recommending DOM intervention to the patients, enabling timely DOM intervention. There are few reports on the involvement of physical

therapists in the RTW of cancer patients, and most involve patients with breast cancer<sup>20,21</sup>. Our previous study also revealed that preoperative physical performance is related to postoperative RTW in patients with lung cancer<sup>11</sup>. When providing DOM support, a patient request is required for the intervention of the DOM<sup>6</sup>. However, patients rarely recognize this need, even when they are in a situation that requires professional intervention. In our previous research on perioperative working patients with lung cancer, only 3 of 59 patients (5%) were offered DOM intervention<sup>11</sup>. It is crucial for physical therapists, who spend considerable time in contact with patients during physical therapy, to determine the need for intervention and promote health and employment support by specialists based on the patient’s challenges and physical performance, and to actively recommend DOM intervention to patients.

A systematic review has reported that perioperative rehabilitation during abdominal surgery is effective in preventing pulmonary complications<sup>22</sup>. It has been reported that patients with sarcopenia before pancreaticoduodenectomy are at risk of developing postoperative pancreatic fistula and have a poor prognosis<sup>23,24</sup>. Although this patient did not have obvious sarcopenia preoperatively, he was administered aggressive physical therapy preoperatively, considering the high risk of postoperative complications due to disease characteristics. As a result, although the patient did not develop any postoperative pulmonary complications, the fever, and prolonged drainage due to a pancreatic fistula resulted in a decline in physical performance at the time of discharge. Preoperative rehabilitation for patients undergoing pancreaticoduodenectomy has been reported to significantly reduce the incidence of postoperative pancreatic fistula<sup>25</sup>. Comprehensive perioperative rehabilitation is needed to prevent the development of postoperative pancreatic fistulas.

In addition to the decline in physical function after surgery, our patient was scheduled to continue chemotherapy for an extended period after his RTW, and there were concerns about physical effects such as fatigue and decreased physical performance due to side effects associated with chemotherapy. Although Japan’s medical system does not approve outpatient rehabilitation for cancer patients, the DOM team with the physical therapist surmounted this challenge by checking the self-training progress when the patient visited the DOM clinic every fortnight. During outpatient visits after discharge, the physical therapist attended DOM meetings regularly and provided continuous support by sharing the patient’s physical function and self-training methods from the professional perspective of physical therapy. Based on these meetings, the physician in charge of the regular DOM follow-up clinic took over exercise instruction. In this case, the direct and indirect contributions of the physical therapist enabled the patient to build physical strength for return to work. Previous studies reported that work did not necessarily lead to improved health and physical performance among cancer survivors and that continuous support

is required even during work<sup>26)</sup>. In the future, it may be necessary to consider including regular physical performance assessments and rehabilitation in the employment support protocol after RTW.

In Japan, very few facilities like our hospital possess a DOM that specializes in promoting health and employment support. If there is no intervention from the DOM, health and employment support is a personal matter between the attending physician and the workplace. In particular, small businesses that do not have occupational physicians often struggle to decide whether to resume work, provide support methods, and cooperate with medical institutions<sup>6)</sup>. The Japan Organization of Occupational Health and Safety is taking the initiative to train coordinators to promote health and employment support. In the future, many physical therapists will be required to champion the promotion of health and employment support and adopt the role of Coordinator of the Promotion of Health and Employment Support.

## Conclusion

There are few reports on physical therapy in the promotion of health and employment support, and there are no established physical therapy programs. In particular, the Japanese medical system does not approve outpatient rehabilitation for cancer patients, making it difficult for them to obtain rehabilitation support, including RTW assistance, after discharge. This case report suggests that physical therapists play a crucial role in providing continuous support for patients, from perioperative rehabilitation to DOM intervention to build physical strength for return to work.

In collaboration with the DOM, perioperative rehabilitation may contribute to a smooth RTW in cancer patients experiencing decreased work ability after surgery. Therefore, physical therapists should actively promote health and employment support. In the future, the physical therapist will be required to acquire professional qualifications as a Coordinator of the Promotion of Health and Employment Support.

**Acknowledgments:** This study was supported by the Workers' Disease Clinical Research Projects Grant-in-Aid (230301-01) of the Ministry of Health, Labour and Welfare of Japan. We would like to thank the staff of the University of Occupational and Environmental Health for their cooperation in this study.

**Consent for Publication:** In accordance with the Declaration of Helsinki and the Ethical Guidelines for Medical and Health Research Involving Human Subjects, the case report was explained to the subject, and written informed consent was obtained, taking into consideration the protection of personal information.

**Conflict of Interest:** The authors declare that they have no conflicts of interest.

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## 4

上肢および手指麻痺に対する  
リハビリテーションロボットを  
用いた治療展開Development of Treatment Using Rehabilitation Robots for  
Upper Limb and Hand Paralysis

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Key words : リハビリテーション治療 / 上肢訓練支援ロボット / 手指型 / 効果 / 操作性

要  
旨

高齢化社会は日本を筆頭に世界的に進み、働く高齢者が増えエイジフリーな職場環境が求められ、医療現場でもその一策として上肢訓練支援ロボットの開発が進み、最近では手指型が注目されている。機能訓練を十分量、反復して安全に行うことができ、作業療法の併用療法として効果のエビデンスは蓄積され、巧緻運動訓練も一部可能となった。治療として日本で利用できる環境は整いつつあるが、介入時間に制約がある中で簡便性、操作性、費用対効果の問題は避けて通れない。ロボットを使用しながら改良し進化を続ける時期であり、将来的には機能改善を巧緻性につなげる役割も期待され、上肢リハビリテーションの大きなブレイクスルーが得られる可能性もある。

## はじめに

2023 年高齢社会白書<sup>1)</sup>では高齢化率（65 歳以上人口割合）29.0%、75 歳以上人口 15.5%と上昇が続いている。労働力人口総数に占める 65 歳以上の者の割合は 13.4%で、現在仕事をしている 60 歳以上の約 9 割が高い就業意欲をもっている。公的年金支給開始年齢の引き上げも進み、2021 年に施行された改正高年齢者雇用安定法<sup>2)</sup>で 65 歳までの雇用確保は義務に、70 歳までの就業確保は努力義務になり 70 歳定年が現実のものとなってきた。

エイジレスに働ける社会の実現に向けたエイジフレンドリーガイドライン<sup>3)</sup>のもと、エイジアクション 100<sup>4)</sup>の中で腰痛予防が重要項目として挙げられ、同一姿勢や反復作業を減らすことの周知が行われ、本学でも労災予防の取り組みが進んでいる。高齢化は世界的にも急速に進展しており、今後は高齢者になっても働き続けるためには何をすればよいかをより具体的に考える必要がある。

リハビリテーション医療に携わるわれわれは、介入時間が限られ、かつ、重症度にかかわらず必要十分量の訓練を反復して提供する中で、医療者の負担軽減の一環としてロボットリハビリテーションを導入し、結果として患者の機能向上をより高く設定できることが求められる。本稿では上肢ロボットリハビリテーションの治療展開について、本誌第 59 巻 4 号<sup>5)</sup>に基づき報告する。

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図1 手指機能と巧緻性

## 上肢訓練リハビリテーションの現状と問題点

従来、ロボットにはヒトの手指機能や巧緻性（図1）の再現は困難と考えられてきた。産業用ではロボットアームの先端に把持を目的としたシンプルな2指のハンドや道具を付けたシステムが主体だが、24関節・20自由度をもつ5本指ロボットハンド（日本バイナリー株式会社製、Shadow Dexterous Hand）を用い、対立の再現が可能となった。手先の感覚も多機能センサを組み合わせ、力触覚を定量化して利用するリアルハプティクス®（慶應義塾大学）を用い、トマトや卵をつぶさずに把持する技術など挑戦が進化している<sup>6)</sup>。5指駆動型の筋電義手（オットーボック株式会社製、bebionic ハンド）も市販され、母指対立位の選択ができ、AI制御で、握りに加え2点・3点ピンチができ、マウスのクリックもできるなど自然な手の動きに近づいてきている。

訓練用ロボットは、基礎的な訓練の反復運動をアシスト機能（運動・感覚刺激）で行うことができ、手指型の登場で5指分離運動、巧緻運動も一部行うことができるようになった。複数の患者の個性差に合わせて装着する点、患者自身の機能・能力の向上に合わせて設定を変更する点が上述の他機器と違うため、自由度は低く、感覚補助はなく、対立や巧緻運動も限られ、直接ADLに用いることはできない。効果のエビデンスは蓄積され<sup>5,7,8)</sup>、一部のロボットが医療保険適応（運動量増加機器加算）となった。

## 手指型訓練支援ロボット

手指の訓練支援ロボットは、手指以外の上肢訓練を直接ロボットで行う機構がなく、必要に応じアームサポートで手の位置を調整していることを考慮し、手指型として独立して考えるべきである。手指型の中で分類するとすれば外骨格型、末梢効果器型に加え、グローブ型がある（表1）。



表1 上肢の訓練支援ロボットの例と主に行える訓練

EsoGLOVE 以外は 2023 年 10 月現在運動量増加機器加算の保険適応を受けている。現時点でロボットで直接 ADL 訓練を行えるものはない。

構造		ロボット名	ROM 訓練	筋力強化訓練	巧緻運動訓練	ADL 訓練
上肢	末梢効果器型	Physibo SPTD	前腕回内外		リーチ	
		Physibo RTD				
	外骨格型	HAL (単関節)	肘			
手指	末梢効果器型	AMADEO	母指対立・2～5 指屈伸			
	外骨格型	MELTz	手指屈伸		ピンチ・握り	
	グローブ型	EsoGLOVE	手指屈伸		ピンチ・握り	

末梢効果器型は AMADEO (インターリハ株式会社) が挙げられ、前腕を固定し、指先につけたマグネットを用い指先を誘導することで 5 指分離独立したアシスト運動 (または他動) を、表面筋電サポート下で行う。等尺性筋力、range of motion (ROM)、痙縮の評価を定量的に行える点<sup>9)</sup>が特徴である。装着は簡便であり、ゲーム形式で楽しく訓練を行えるが、手先は固定されるので巧緻運動訓練はできない。

外骨格型は MELTz (MELTIN 社、住友ファーマ株式会社) が挙げられる。手指自体をリンクの一部としたリンク構造を用いたハンドユニット (重量 500 g、1 サイズですべての手に対応) を装着し、インピーダンス制御のもとモーターでワイヤーを動かすことにより、母指の (CM)/IP/MP 関節、2~5 指の MP/PIP 関節を運動させ、1 軸・1 自由度 (屈伸) のアシスト (他動) 運動を、表面筋電 (AI 解析) サポート下で行う。握り・ピンチ (2 指・3 指) を最速で約 5 秒に 1 回程度 (屈曲に約 2 秒) 行うことができる。

急性期から亜急性期の手指麻痺患者に実際に使用してみると、初回使用時に各指の屈伸軸の設定・装着に時間がかかるが、翌日からは各指の可動域をそれぞれ簡単に変更できた。AI 設定後の「ぐー」と「ぱー」の動作は柔らかく、20 分程度他動・アシスト訓練を安全に行えた。患者のロボットに対する印象は良好であり、2~3 週間の使用にも前向

きに取り組んでいただけた。慢性期脳卒中患者のランダム化比較試験 (randomized controlled trial: RCT) では MELTz を用いたアクティブアシスト運動を 40 分/回、週 2 回、4 週間行うことで、MELTz を用いた他動運動を同様に行った群よりも有意な麻痺の改善を認めたと報告されている<sup>10)</sup>。

グローブ型でわれわれが導入している EsoGLOVE (インターリハ株式会社) は、グローブ (S/M/L サイズ) を装着し空気圧で 5 指の手指の屈伸について、1 軸・1 自由度 (屈伸) のアシスト (他動) 運動を行う。握り・ピンチ (2 指・3 指) を最速で 20 秒に 1 回程度 (屈曲で 5 秒) 行うことができる。装着は簡便で、20~60 分程度他動・アシスト訓練が安全に行える。画面には手の動きの見本が表示され、アシストの閾値に達した場合は正のフィードバックがかかる。母指の軸を対立しやすい方向に調整することで 2 指・3 指ピンチ動作が容易となるが、指腹と指腹が確実に接触するわけではなく、手先のすべり止めもないため、1~2 cm 角程度のブロックがつまめる最小単位となる。上肢近位機能がよい患者は比較的正しい巧緻運動訓練を積極的に行うことができ、患者のロボットに対する印象は良好であり、2~3 週間の使用にも前向きに取り組んでいただけた。

当院で施行した EsoGLOVE の効果について、後方視的に検討した。初発脳卒中で手指 Brunnstrom Recovery Stage (BRS) が 2 以下、発症 3

日以内にリハビリテーション訓練を開始し、発症3週以内に EsoGLOVE による訓練を開始し、発症から6~8週間当院に入院していた患者を抽出し、同様の重症度・経過で EsoGLOVE を行わず通常の訓練を行った患者と比較した。両群ともに発症してから転院までに有意な手指 BRS の改善を示し、ロボット群は通常群と比べて有意な改善を示した。使用感や患者・療法士の負担も問題なく、RCT に取り組むべく準備を進めている。

## 今後の訓練支援ロボット

神経可塑性の原則は神経損傷後「より早く」「より多く」である<sup>11)</sup>。ロボット訓練は神経可塑性変化を生じるという報告<sup>12)</sup>もあるが、最新のレビューでも特に急性期での比較研究は乏しく、その要因として麻痺側上肢の訓練時間の確保が難しい<sup>13)</sup>ことが挙げられ、現状では必要な量 (Dose ≡ 総介入量)、強度 (Intensity ≡ 1 回量) に達していないのではないかとされている<sup>14)</sup>。

上肢訓練を行うタイミングや量、強度、介入内容について議論する際は、①方法で検討された強度と実際に行った強度で違いがある可能性や、②同じロボット機器を使っている他動からアシストに切り替えるなど難易度を上げて介入している可能性について考慮し、記録に残した結果を考察すべきという意見<sup>15)</sup>が出ている。

また、主要評価項目に麻痺は上肢 Fugl-Meyer Assessment、巧緻性は Action Research Arm Test が用いられることが多いが、手指の機能・巧緻性の多様性に対応した、より簡便な評価が求められている。

そして、ロボットに期待されるものに操作性、正確性、耐久性、コスト<sup>16)</sup>があるといわれるが、日本で訓練支援ロボットが普及するヒントになると考えている。簡便に不具合なく使えてこそ医療職の負担が軽減するという前提のもと、多くの患者に適応

できるロボットを安価でつくれば、医療保険だけでなく、介護保険でも気軽に使えるものになり、ロボットが進化できる環境が整うと考える。

## おわりに

上肢の訓練支援ロボットは、作業療法の訓練を補助する有用なツールとして一般化され、手指の訓練支援ロボットも含め、選択肢は増加している。基礎的な訓練ができるロボットを常時使えるような環境が整い、それを使いこなす文化が成熟すると、数年後にはさらに進化が進み巧緻性の向上に向けた正確な動きを補助できるロボットの開発ができ、その先には直接 ADL 訓練が行えるものが…と考えている。まだまだ「伸びしろ」がある分野であり、研鑽を続ける所存である。

本論文発表内容に関して申告すべき COI はなし。

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# 下肢訓練支援ロボット

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## — Key Words —

下肢訓練支援ロボット, リハビリテーション治療, 分類, 外骨格型

連載  
一覧

①リハビリテーションロボットの定義・分類  
②上肢訓練用ロボット

③下肢訓練支援ロボット  
④介護ロボット

下肢訓練支援ロボットを用いた歩行リハビリテーションは、ここ数十年で大きく進歩した技術であり、脳卒中や脊髄損傷をはじめとした麻痺や可動域制限を生じている患者に用いられる。外骨格型を主流とし、効果のエビデンスが構築されてきている反面、操作性や個別性、経済性の面で課題が残り、臨床現場での活用とのギャップは大きい。

本稿では本邦で使用されている代表的な下肢訓練支援ロボットを挙げながら、その分類、特徴と効果、課題に分けて解説する。本稿を通じて臨床現場での活用の一助となれば幸いである。

## 下肢訓練支援ロボットの分類

下肢訓練支援ロボットを理解するうえで、ロボットの「構造」と目的となる「動作」、実際に動かす関節の「運動」の3つに分ける考え方が提唱されている(図1)<sup>1)</sup>。

「構造」は末梢側を固定して関節を動かす末梢効果器型と、関節軸を外骨格で設定し関節を動かす外骨格型に分けられる(表1)<sup>1)</sup>。外骨格型は重度片麻痺などの障害をもつ患者によく使用される一方、軽度から中等度の障害をもつ患者には末梢効果器型を用いた機能的な訓練がより有効であるとされる<sup>2)</sup>。

下肢訓練支援ロボットは、世界で圧倒的なシェアを誇る Lokomat<sup>®</sup> (Hocoma 社, スイス) を中心とした外骨格型が多い<sup>1)</sup>。Lokomat<sup>®</sup> は脊髄損傷者に

対する療法士によるステップ補助を代替すべく開発されたロボットであるが<sup>3)</sup>、脳卒中や頭部外傷、パーキンソン病などを対象とした報告も多数ある。トレッドミル上で、重力の影響を除去するためハーネスを用い<sup>1)</sup>、股関節と膝関節に装備されたモータにより下肢の歩行運動パターンを実現する<sup>3)</sup>。2021年より本邦でも販売が開始されている。

「動作」に関して、下肢訓練支援ロボットの目的の活動のほとんどが歩行である<sup>1)</sup>。訓練場所としては据付(トレッドミルなど)か平地かに分けられ(表1)、据付タイプは大型で設置場所を選ぶ一方、平地で用いるロボットは携帯性に優れている。

「運動」は補助様式、動作範囲(自由度・次元)、作用する関節(左右両側)に分けて考え、補助様式には他動、アシスト(患者の力や位置を感知し補助する)、自動がある<sup>1)</sup>。下肢は自由度を最小限に落として3次元で歩行訓練を行うものが多いが、後述する歩行アシストや足首アシスト装置などの単関節タイプも開発されている<sup>1)</sup>。

## 本邦の代表的な下肢訓練支援ロボット

本邦で使用されている代表的な下肢訓練支援ロボットを表2に示す。いずれも外骨格型である。

トレッドミル上で訓練を行うロボットとして、ウェルウォーク WW-1000(トヨタ自動車株式会社)が挙げられる。ロボット脚、低床型トレッドミル、

Current Status and Issues of Lower Limb Training Assist Robots

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構造		動作		運動	
構造		自動化率		補助様式	
End-effector (末梢効果器)		全自動		他動	
Exoskeleton (外骨格)		半自動		アシスト	
Others		訓練場所		自動 (抵抗)	
フィードバック		起立歩行		作用する関節	
視聴覚		起立		股	
VR		立位		膝	
皮膚		歩行		足	
ハプティクス				左右	
達成度				両側	
				片側	

図1 下肢訓練支援ロボットの分類

(越智光宏, 佐伯 覚: ロボットリハビリテーション治療最前線. Jpn J Rehabil Med 57: 2020 を改変して転載)

VR: virtual reality

表1 下肢訓練支援ロボットの構造による分類とその一例

構造	動作 (訓練場所)	モデル
末梢効果器型	据付 (プレート上)	Gait Trainer, G-EO System
外骨格型	据付 (トレッドミル上)	Lokomat®, ウェルウォーク, HAL®, 歩行アシスト, 足首アシスト装置
	平地	HAL®, 歩行アシスト, 足首アシスト装置

表2 本邦の代表的な下肢訓練支援ロボット

ロボット名	作用関節	片/両側	補助様式	訓練場所	適応 (対象)	参考価格
ウェルウォーク WW-1000 (トヨタ自動車 株式会社)	膝関節屈伸	片側	アシスト	据付 (トレッドミル)	片側下肢に重度の麻痺を有する者	本体: 2350 万円 (WW-2000)
HAL® (筑波大学)	股関節屈伸/ 膝関節屈伸	片/両側	随意制御 (アシスト)/自律制御 (他動)	平地/ トレッドミル	両脚タイプ: 希少性神経・筋難病疾患を有する者 (医療機器として承認)	レンタル: 40 万円/月 初期導入費用: 65 万円/台
歩行アシスト (本田技研工業 株式会社)	股関節屈伸	両側	アシスト	平地/ トレッドミル	麻痺側の立脚が安定した者	2020 年末に販売終了
足首アシスト装置 (株式会社安川電機)	足関節底背屈	片側	アシスト	平地/ トレッドミル	脳卒中片麻痺患者で AFO を用いて平地歩行が自立している者	180 万円

HAL: Hybrid Assistive Limb, AFO: ankle foot orthosis



安全懸架装置（部分体重免荷装置としても使用可能）、脚部免荷装置、患者用モニタ、操作パネルから構成される<sup>4)</sup>。現在発表されている下肢訓練支援ロボットの多くは両下肢を制御する設計となっているが、ウェルウォーク WW-1000 では麻痺側下肢のみをアシストして非麻痺側下肢の運動を制限せず、また、骨盤帯がなく体幹を制御しないことから片麻痺者の運動学習に期待されている<sup>4)</sup>。さらに、後継機である WW-2000 が 2020 年に発売開始となった。マーカレスの歩行分析機能を搭載し、検出した修正すべきパラメータの設定支援が可能となったことが特徴である。

平地でもトレッドミル上でも使用可能なロボットは Hybrid Assistive Limb<sup>®</sup> (HAL<sup>®</sup>、筑波大学)、歩行アシスト（本田技研工業株式会社）、足首アシスト装置（株式会社安川電機）などである。

HAL<sup>®</sup> は両側または片側の脚部が腰フレーム（骨盤帯）に連結され、股関節・膝関節のモータは HAL<sup>®</sup> 独自の随意制御と自律制御の組み合わせにより制御される<sup>4)</sup>。随意制御では使用者の筋電図を検出してモータの制御を行い、自律制御では重心移動などの情報から使用者の動作を予測してあらかじめパターン化しておいた基本動作を再現する<sup>4)</sup>。

両脚タイプの HAL<sup>®</sup> 医療用は希少性神経・筋難病疾患に対して歩行速度の改善を認め、2015 年に医療機器として承認された<sup>4)</sup>。また、脳卒中への適応拡大に向けて国内で治験が行われ、脳卒中片麻痺患者 52 名を対象としたランダム化比較試験 (randomized controlled trial: RCT) で、単脚タイプの HAL<sup>®</sup> を装着し歩行プログラムを行った群は、通常歩行リハビリテーション群と比較して 6 分間歩行距離で優越性を示す有意差が認められた<sup>5,6)</sup>。脳卒中患者に対する医療用 HAL<sup>®</sup> の製造販売承認申請の準備が行われている段階である。

歩行アシストは 2020 年末に販売終了となったが、骨盤部に装着する本体、両側的大腿フレーム、両側の股関節外側に位置するモータから構成され、股関節の屈曲/伸展を補助する<sup>4)</sup>。装着者の歩行パターンに合わせて補助を行う「追従モード」と、歩行の対称性を改善するように補助を行う「対称モード」がある<sup>4)</sup>。本田技研工業株式会社が開発した二足歩行ロボット ASIMO に搭載されている「倒立歩行モデル」を採用している。膝・足関節の動きには直接関

与しないため、麻痺側の立脚が安定した症例で、左右対称性や歩幅の増加を目的とした使用が推奨されている<sup>4)</sup>。

パーキンソン病患者に対して歩行アシストを用い歩行訓練を行った結果、即時的効果として歩幅の改善を認めたという報告がある<sup>7)</sup>。また、左右の対称性が損なわれた歩容を呈したパーキンソン病患者に対して歩行アシストを用い歩行訓練を行った結果、即時的に歩行の左右対称性の改善を認めたという報告もある<sup>8)</sup>。歩行アシストは下肢振り出しのサポート量を左右それぞれ調整できるため、パーキンソン病に対する新しい効果的な歩行訓練となる可能性があると考えられている<sup>8)</sup>。

さらに、慢性期下肢機能障害例（パーキンソン病 17 例、神経障害 10 例、下腿義足 1 例）に対して歩行アシストを使用し歩行訓練を行った過去の調査<sup>9)</sup> では、歩行アシストがロコモティブシンドロームやサルコペニアによる歩行速度低下の改善に役立つ可能性が示唆されている<sup>10)</sup>。歩行改善のメカニズムとしては、歩行障害があり歩行量が減っていた症例が、歩行アシストを用いることにより歩行が容易となり歩行訓練が順調に行えたためと考えられている<sup>10)</sup>。

足首アシスト装置（図 2）は福祉機器として販売されているモータ付足継手付短下肢装具 (ankle foot orthosis: AFO) であり、腰に巻くコントローラで角度とトルクを設定することで歩行中の底背屈補助を行うことができる<sup>11)</sup>。拇趾球部と踵部の足圧センサーの情報をもとに、底背屈動作をモータでアシストする。小型であり、脳卒中片麻痺患者で AFO を用いて平地歩行が自立している症例に適応があると考えられる<sup>11)</sup>。近年、強力で小型のサーボモータが開発され、ロボットのダウンサイジング化が進んでいる。

## 下肢訓練支援ロボットの特徴と効果

下肢訓練支援ロボットの特徴は、療法士の負担を軽減しつつ十分量の訓練を安全に行えることで、多くのロボットが反復動作を得意としており、いったん設定が終われば重度の障害がある者でも決められた量の運動を正しくこなすことができる点が挙げられる<sup>1)</sup>。また、運動の回数やパターン、時間を定量的に評価することができ、確実なフィードバック



図2 足首アシスト装置

コントローラと短下肢装具で歩行中の底背屈補助ができる。

a: 歩行の実際, b: コントローラ画面で補助量 (HC: heel contact, MS: mid stance, HO: heel off, SW: swing) の調整が可能, c: 短下肢装具 (モータ付足継手, 中敷部に足圧センサー設置, S/M サイズあり)。

を行える点も利点である<sup>1)</sup>。

Cochrane Database のシステマティックレビュー<sup>12)</sup>では、下肢訓練支援ロボットを脳卒中発症3か月以内の歩行不能の患者に用いると安全に十分な歩行訓練を行え、歩行自立度が向上するというエビデンスが得られている<sup>13)</sup>。「脳卒中治療ガイドライン2021」<sup>14)</sup>でも、歩行ができない発症後3か月以内の脳卒中患者に対して、歩行支援ロボットを用いた歩行訓練を行うことは妥当である(推奨度B, エビデンスレベル中)と述べられているが、脳卒中患者における下肢訓練支援ロボットを用いた歩行リハビリテーションに関する最新のシステマティックレビュー<sup>2)</sup>では、重症度は重度障害のほうが、時期は発症後3~6か月でよりよい効果が得られ、従来の理学療法の代わりとして行うのではなく併用すべきであるとしており、推奨する時期にややずれがある。

また、下肢訓練支援ロボットを用いるうえでは重症度を考慮する必要がある。重度障害に対しては、トレッドミル上で体幹を懸垂することで早期からの反復歩行訓練が安全に施行可能となる。一方で、こ

のような症例に平地で使用する懸垂機構のないロボットは適しているとは言えず、筆者らが用いる際は安全面に配慮してハーネスを併用することが多い。下肢訓練支援ロボットにはさまざまな種類があるが、目的や適応が異なることを念頭に置いて選択すべきである。

### 下肢訓練支援ロボットの課題

下肢訓練支援ロボットの普及が進まない要因として、初期設定や調整に時間や労力を要するといった操作性の問題がある。また、ヒトには障害の程度に加え身長や体重といった個別性がある一方で、現状ではロボットはサイズが限られており、従来の個人用装具と比べて個別性に対応しづらいという点も挙げられる。さらに、高額なものが多く(参考価格: 表2)、費用対効果を踏まえると経済性の面からも幅広い普及には至っていない。

これらの解決すべき問題があるほか、ロボットでなければ代えがきかないという場面は多くはない。ロボットの反復動作は歩行が多く、日常生活動作



(activities of daily living: ADL) に直結しやすい反面、1人介助で有効な歩行訓練が行えるようになると応用的な訓練も行える理学療法の方が有利である<sup>1)</sup>。ADLに直結する訓練を行うためには、ロボット単独で訓練を行うのではなく、理学療法や作業療法と組み合わせる必要がある<sup>1)</sup>。現状での急性期の歩行困難者における下肢訓練支援ロボットの用途としては、個人用装具完成までの期間、装具の代用として用いることが現実的である。

さらに、ロボットが有効な患者の特徴や、ロボットを使用する適切な時期や量、頻度、期間、具体的な機器の種類について、まだコンセンサスが得られていないことも課題である<sup>2)</sup>。個々のロボットについては、介入前後で歩行能力が改善したとする報告が多いが、評価項目や対照群の練習内容が一定でないことが研究結果の統合を困難にしている<sup>4)</sup>。重度障害については Functional Ambulation Category (FAC)を用いた歩行自立度で評価可能である一方、軽度から中等度障害では適切な機能的評価項目が不足しており改善を客観的に示すことが難しい。重度障害ではコンセンサスが得られつつあるが、その他に関してはさらなる研究が求められる。

### これからのリハビリテーション治療のために

ヒトの個性の高さがゆえに訓練に労力を要する場面は少なくないものの、リハビリテーション治療継続により身体機能の改善がみられることから、少しでも療法士の負担を軽減しつつ必要な治療を行えたら、というのが現場の思いである。今後はより汎用性が高く実用的なロボットが必要であり、新たなものに期待しつつ、よりよいロボットとはどのようなものであるかを引き続き考えながら研鑽を積んでいきたい。

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# 令和6年度労災疾病臨床研究事業

## Ⅱ. 分担研究報告書

### 4. エキスパートパネルディスカッション

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## エキスパートパネルディスカッション

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### 研究要旨：

【目的】本分担研究では、「1. 高年齢労働者の転倒災害に対する事業所実態調査【事業所調査】」、「2. 高年齢労働者の転倒災害に対する医療機関実態調査【医療機関調査】」、「3. 早期復職へ向けたリハビリテーション治療プログラムの開発【プログラム開発】—1) 加齢モデル調査研究【加齢モデル】、2) 早期復職支援プログラム【早期支援】、3) 高齢労災被災患者の二次障害予防【二次障害予防】」で得られた知見をもとに、結果を取りまとめ、専門家による検討を行う。

【方法】上記分担研究1～3で得られた知見をもとに、高年齢労働者の転倒災害の特徴ならびに対応について、臨床的妥当性や有用性について研究分担者・協力者を中心に検討を行う。

【結果】①高年齢労働者の転倒災害後の離職が一定数存在し稀な事象ではない。②離職の背景には医学的要因や職務関連要因が存在する。③高年齢労働者の転倒災害後の復職を促進するためには、事業所と医療機関の連携強化、治療と就労の両立支援の充実、さらに業務内容の柔軟な調整が可能な体制整備が重要である。④転倒による被災労働者の障害部位は、脊椎・脊髄、上肢及び下肢の割合が同程度ある。⑤障害が重度の場合、複数の医療機関をまたいでの診療となるため、症状固定時期の判断が難しく、どうしても症状固定までの期間が長くなる傾向にある。⑥症状固定の判断をする際に必要な検査や基準として、自覚症状、画像検査（レントゲン、CR、MRI）、筋力や関節可動域検査などの機能評価の他、JOA スコア、日常生活動作、上肢機能検査などが重要である。⑦身体機能評価において、非侵襲的な身体活動量計や体組成計を用いた客観的かつ信頼性の高い測定値を用いることにより、適切に身体能力を評価することが可能となり、効果的な治療プログラムの立案に有用である。⑧より早期のリハビリテーション治療介入が予後や転帰を改善する。

【考察】結果に提示した①～⑧の項目は、高年齢労働者の転倒災害等の特徴や対応である。転倒災害は稀な事象ではなく、離職に至ること、療養期間も長期にわたることが多く、医療機関間の連携、医療機関と事業所と連携が重要であることが改めて確認された。これらの情報については、学術誌をはじめ、ホームページなどを含め広報啓発することで、今後の包括的な対策等につなげてゆく必要がある。

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## A. 研究の背景と目的

業務に起因した転倒災害などの労働災害（労災）被災高齢労働者は軽度な障害であっても、もともと身体予備能が乏しく治療・療養期間が長期化しやすく、復職後も繰り返し労災を生じるリスクが高いという特徴がある。被災後のリハビリテーション治療も長期化し、在宅復帰や社会参加そのものが困難となることも多く、治療を担当している医療機関においては症状固定時期の判断が極めて難しい状況がある。その結果、彼らの社会復帰が著しく遅れ、個人レベルの不利益のみならず社会経済的に大きな損失をきたしている。

このような背景のもと、高齢の転倒災害被災労働者に対して、十分な治療を行い再び社会復帰に至る過程をサポートする必要がある。すなわち、高齢転倒災害被災者における症状固定、在宅復帰や社会復帰に関する必要な評価項目や支援方法について医学的な観点から適切な方法を確立する必要がある。

本分担研究では、「1. 高齢労働者の転倒災害に対する事業所実態調査【事業所調査】」、「2. 高齢労働者の転倒災害に対する医療機関実態調査【医療機関調査】」、「3. 早期復職へ向けたリハビリテーション治療プログラムの開発【プログラム開発】— 1) 加齢モデル調査研究【加齢モデル】、2) 早期復職支援プログラム【早期支援】、3) 高齢労災被災患者の二次障害予防【二次障害予防】」で得ら

れた知見をもとに、結果を取りまとめ、専門家による検討を行う。

## B. 方法

上記分担研究1～3で得られた知見をもとに、高齢労働者の転倒災害の特徴ならびに対応について、臨床的妥当性や有用性について研究分担者・協力者を中心に検討を行った。

## C. 結果

### ① 高齢労働者の転倒災害後の離職が一定数存在し稀な事象ではない。

高齢労働者の転倒災害が発生した事業所のうち、6.6%が転倒災害後の被災者の離職を経験している。高齢労働者は転倒災害被災後に、「治療の遷延」「後遺障害が高度」などの医学的要因を背景に離職するケースが存在する。

### ② 離職の背景には医学的要因や職務関連要因が存在する。

復職支援において「医療機関との連携」「通院治療への配慮」「作業内容の変更」が行われていない事業所では、復職に至らないケースが多い傾向がある。

### ③ 高齢労働者の転倒災害後の復職を促進するためには、事業所と医療機関の連携強化、治療と就労の両立支援の充実、さらに業務内容の柔軟な調整が可能な体制整備が重要である。

被災労働者への個別対応、当該事業所の業種や規模に応じた対応方法をカスタ

マイズする必要がある。現に様々な取り組みを実施、あるいは、何らかの対応を考慮している事業所がある。また、有効なリハビリテーションを行うためにも、個別評価や指導が重要である。

**④ 転倒による被災労働者の障害部位は、脊椎・脊髄、上肢及び下肢の割合が同程度ある。**

整形外科での入院期間は 15～30 日、リハビリテーション科での入院期間は 15～90 日、症状固定期間としては整形外科では 91～180 日、リハビリテーション科では 31～540 日（181～365 日が最多）であった。

**⑤ 障害が重度の場合、複数の医療機関をまたいでの診療となるため、症状固定時期の判断が難しく、どうしても症状固定までの期間が長くなる傾向にある。**

症状固定に関して、いわゆる後方病院での判断を行う場合には、前医への問い合わせなどが実施されていることも多く積極的な医療連携（情報交換等）が重要である。また、復職支援にあたっては、医療機関と事業所との更なる連携強化が必要である。

**⑥ 症状固定の判断をする際に必要な検査や基準として、自覚症状、画像検査（レントゲン、CR、MRI）、筋力や関節可動域検査などの機能評価の他、JOA スコア、日常生活動作、上肢機能検査などが重要である。**

以上の検査結果を踏まえ、改善度合いなどの経時的変化を確認し、総合的に判断する。

**⑦ 身体機能評価において、非侵襲的な身体活動量計や体組成計を用いた客観的かつ信頼性の高い測定値を用いることにより、適切に身体能力を評価することが可能であり、効果的な治療プログラムの立案に有用である。**

近年のリハビリテーション技術や機器の発展は目覚ましく、体組成計測定による位相角（PhA）は個体の身体機能や栄養状態など就業能力を反映する筋肉量と強い関連性を有する。また、AI による姿勢推定による転倒予防など、二次災害を防ぐシステムが実用化レベルに達している。今後、経費と有効性の兼ね合いで労働現場に導入されることが考えられる。

**⑧ より早期のリハビリテーション治療介入が予後や転帰を改善する。**

長期入院によるリハビリテーション治療継続には地域レベルでの連携パスシステムの活用、入院以外の長期フォローではオンラインによる個別リハビリテーション指導が役立つ可能性があり、両立支援システムを活用することで復職を促進することができる。

## **D. 考察**

結果に提示した①～⑧の項目は、高年齢労働者の転倒災害等の特徴や対応である。転倒災害は稀な事象ではなく、離職に至ること、療養期間も長期にわたることが多く、医療機関間の連携、医療機関と事業所と連携が重要であることが改めて確認された。

これらの情報については、学術誌をはじめ、ホームページなどを含め広報啓発することで、今後の包括的な対策等につなげてゆく必要がある。

## **E. 研究発表**

なし





# 令和6年度労災疾病臨床研究事業

## Ⅱ. 分担研究報告書

### 5. 情報公開

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## 情報公開

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### 研究要旨：

本分担研究では、「分担研究1、2及び3」で得られた結果に基づき、各専門家による議論を実施し（分担研究4）、その報告内容について情報公開を行う。産業医科大学医学部リハビリテーション医学講座ホームページで本研究結果を公開することにより、高年齢労働者の転倒予防等の労災事故防止、事故後の社会復帰促進等につながることを期待している。

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## A. 研究の背景と目的

業務に起因した転倒災害などの労働災害（労災）被災高齢労働者は軽度な障害であっても、もともと身体予備能が乏しく治療・療養期間が長期化しやすく、復職後も繰り返し労災を生じるリスクが高いという特徴がある。被災後のリハビリテーション治療も長期化し、在宅復帰や社会参加そのものが困難となることも多く、治療を担当している医療機関においては症状固定時期の判断が極めて難しい状況がある。その結果、彼らの社会復帰が著しく遅れ、個人レベルの不利益のみならず社会経済的に大きな損失をきたしている。

このような背景のもと、高齢の転倒災害被災労働者に対して、十分な治療を行い再び社会復帰に至る過程をサポートする必要がある。すなわち、高齢転倒災害被災者における症状固定、在宅復帰や社会復帰に関する必要な評価項目や支援方法について医学的な観点から適切な方法確立する必要がある。

本分担研究では、「分担研究1、2及び3」で得られた結果に基づき、各専門家による議論を実施し（分担研究4）、その報告内容について情報公開を行う。

## B. 方法

本分担研究では、「分担研究1、2及び3」で得られた結果に基づき、各専門家による議論を実施し（分担研究4）、その報告内容について情報公開を行う。

## C. 結果

産業医科大学医学部リハビリテーション医学講座ホームページで「高齢労働者に発症した転倒災害等に係る労災補償給付等の範囲に関する研究報告」を公開する予定である。

## D. 考察

ホームページ等で本研究報告を公開することにより、高齢労働者の転倒予防等の労災事故防止、事故後の社会復帰促進等につながることを期待している。

## E. 研究発表

なし



### Ⅲ. 研究成果の刊行に関する一覧表

雑誌

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