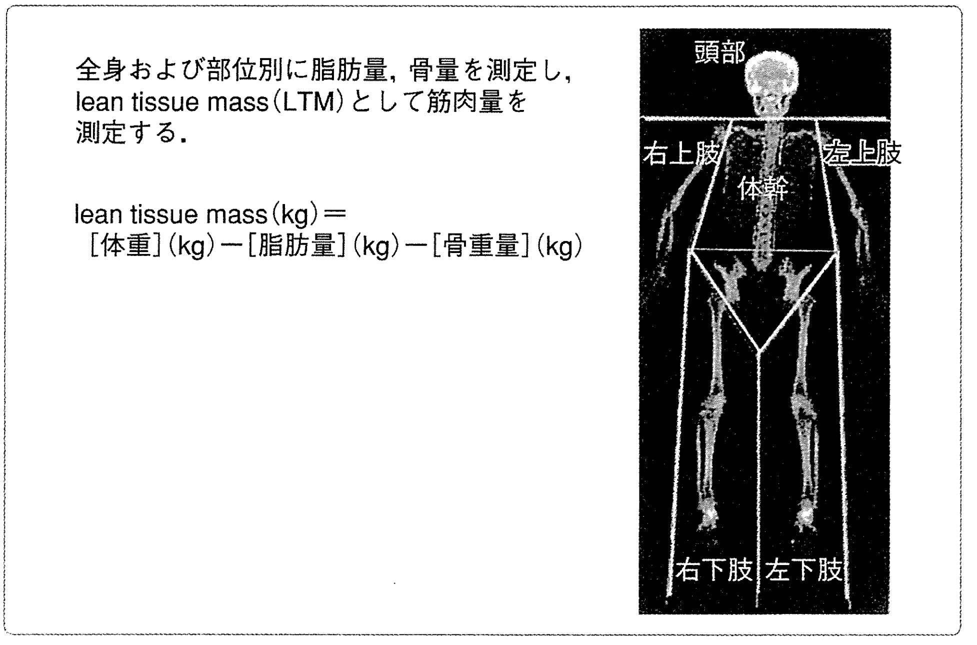


**図 1　二重エネルギー X 線吸収法（DXA）による筋肉量の推定**

ンでは，全身および部位別に重量，脂肪量，骨量を測定することができる．頭部，体幹，左右上下肢の各部位ごとの重量から脂肪量，骨量を除いた徐脂肪徐骨重量（lean tissue mass：LTM）として筋肉量を測定する（図 1）．脂肪，骨を除いた重量を筋量として推定するため内臓の重量などが筋量として含まれてしまうことに注意が必要である．

筋肉量からのサルコペニアの指標として DXA 法で求めた四肢筋量（kg）を身長（m）の二乗で除した値（appendicular skeletal muscle mass/height$^2$：ASM/HT$^2$）が用いられることが多い．ASM/HT$^2$の基準値は若年者における平均値から標準偏差の 2 倍を引いた値が使われている[3]．DXA による放射線被曝量はわずかで，短時間で検査ができるが，やはり高額で移動が難しいためにスクリーニング検査としては利用することは難しい．

インピーダンス法は，両手もしくは両足を介して身体に微小電流を流し，生体の電気インピーダンスを測定し，そこから身体組成を推定する方法である．微小電流の周波数を変化させて使用することで，脂肪だけではなく，筋量や骨密度も推定できる．電極部位として両手，両足の 4 カ所を使用すれば，左右上下肢，体幹の 5 部位の筋量の推定も可能である．比較的安価で，簡単に筋量を推定できるために，筋量のスクリーニングには適しているといえる．

しかし，生体を電気的に検査するために，体内水分量による影響が大きく，食事や就寝の影響があり日内変動が大きい[1,2]．心不全などで浮腫がある場合にも正確な測定はできない．生体電気インピーダンスから体脂肪率や筋量を推定する計算式が測定機器製造各社によって異なり，機器によるばらつきが大きい．心臓ペースメーカーが誤作動を起こす可能性があることにも注意が必要である．

身体計測値から筋量を推定する方法もある．Martin ら[4]は屍体を使って，全身骨格筋量を身長と四肢の周囲長から推定する次のような式を 20 年以上前に発表している．

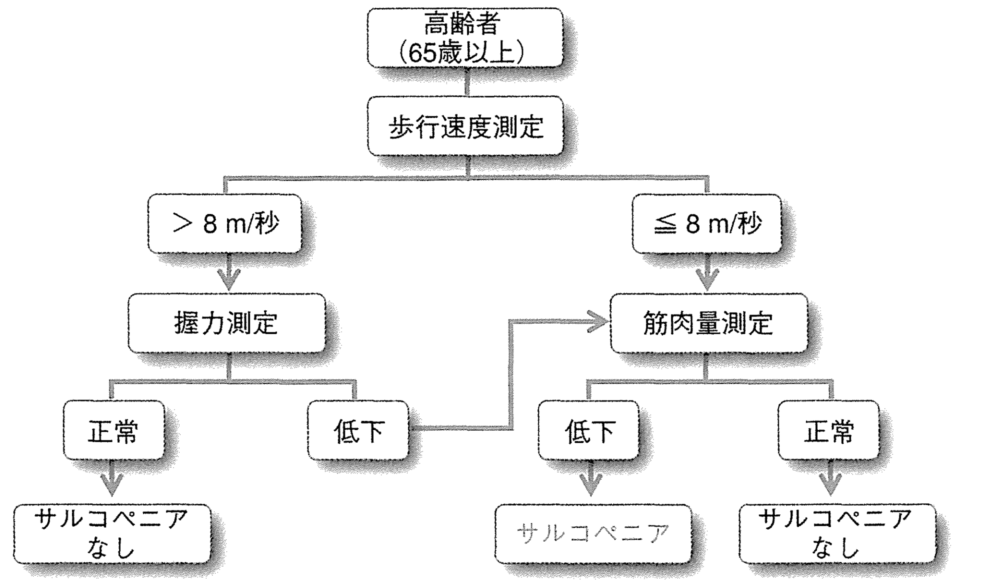


図2　サルコペニアの診断アルゴリズム（文献1より引用改変）

**全身骨格筋量＝身長×0.0533（大腿周囲長)$^2$**
**＋0.0987(前腕周囲長)$^2$**
**＋0.0331(下腿周囲長)$^2$－2445**

全身骨格筋量はkgで身長はcm，大腿周囲長は同部位の皮下脂肪厚で補正したcm，前腕周囲長はcm，下腿周囲長は同部位の皮下脂肪厚で補正したcmである．標準誤差は1.53 kg，$R^2$は0.97である．

上腕の最大周囲長は単独でも高齢者では筋量の指標の一つとして使用できる．上腕部の皮下脂肪厚の測定と合わせて，皮下脂肪量を計算で除いた上腕筋量の指標として上腕筋周囲長（arm muscle circumference：AMC）や上腕筋面積（arm muscle area：AMA）も筋量の指標として使用されることがある．

**上腕筋周囲長＝上腕周囲長(cm)**
**－3.14×上腕部皮下脂肪厚(mm)/10**
**上腕筋面積＝上腕筋周囲長(cm)$^2$/(4×3.14)**

同様に，下腿や大腿部の周囲長が筋量の指標として使用されることもある．

最大筋力は筋の断面積に比例することはよく知られているが，筋肉の「質」は加齢とともに変化し，高齢者では若年者ほどは筋量と筋力は比例しない．サルコペニアは語源からは筋量の減少を示すが，高齢書の運動機能維持のためには，むしろ筋力の方が重要であろう．筋力の指標としては握力が最も簡便で有用である．歩行など高齢者の生活にとって重要な動作に関与する脚筋力の測定には特別な機器が必要であり，スクリーニング検査には適していない．

Millerら[5)]は，サルコペニアのスクリーニングのために簡易型サルコペニア測定法（short portable sarcopenia measure：SPSM）を開発した．SPSMでは，インピーダンス法による徐脂肪BMI[除脂肪体重(kg)/身長(m)$^2$]，握力(kg)/身長（m），椅子の座り立ち5回の時間（秒）を用いて，それぞれに1，1.5，2をかけて合計した数値を計算し，サルコペニアの指標としている[5)]．

表1　サルコペニアの分類（文献1より引用改変）

| 分類 | 原因 |
|---|---|
| **原発性サルコペニア** | |
| 加齢性サルコペニア | 加齢以外の原因がない |
| **二次性サルコペニア** | |
| 身体活動性サルコペニア | ベッド上安静，運動しない生活スタイル，廃用，無重力状態 |
| 疾患性サルコペニア | 高度な臓器障害（心臓，肺，肝臓，腎臓，脳），炎症性疾患，悪性腫瘍，内分泌疾患 |
| 栄養性サルコペニア | 吸収不良，胃腸疾患，食思不振を引き起こす薬物の使用に伴うエネルギー，蛋白質摂取不足 |

ヨーロッパにおける老年学，栄養学などの学会によるワーキンググループである The European Working Group on Sarcopenia in Older People（EWGSOP）は，2010年にサルコペニアの定義と診断についてのヨーロッパ・コンセンサスとして，歩行速度，握力，筋量の3つからサルコペニアの有無を判断するアルゴリズムを作成している（図2）[1]．

## 2．サルコペニアの危険因子

EWGSOP では，サルコペニアを，加齢以外に明らかな誘因がない原発性サルコペニア（primary sarcopenia）と，加齢以外の何らかの要因がサルコペニアを引き起こす二次性サルコペニア（secondary sarcopenia）に分類し，さらに二次性サルコペニアを，ベッド上安静，運動しない生活スタイル，廃用，無重力身体などが原因となる活動性サルコペニア（activity-related sarcopenia），高度な臓器障害，炎症性疾患，悪性腫瘍に伴う悪液質，内分泌疾患などによる疾患性サルコペニア（disease-related sarcopenia），吸収不良，胃腸疾患，食思不振を引き起こす薬物の使用に伴うエネルギーおよび蛋白質摂取不足などによる栄養性サルコペニア（nutrition-related sarcopenia）の3つに分けている（表1）[1]．

これまでに報告されているサルコペニアの危険因子には，遺伝的素因，性別，加齢，身長，体重，BMI，閉経，エストロゲン，テストステロン，総体脂肪量，身体活動，カロテノイド，ビタミンD，分岐鎖アミノ酸および蛋白質摂取量などがある．遺伝的な素因としては，myostain の Lys153Arg 多型，$\alpha$-actinin 3 の R577X 多型が筋量や筋力に関連しているとの報告がある[6,7]．しかし，スポーツ選手では，こうした遺伝子多型の影響があっても，一般の高齢者では，むしろ生活習慣などの影響の方が大きいと思われる．

## 3．加齢とサルコペニア

運動神経線維のうち，筋線維を支配して実際の筋収縮に関与する$\alpha$運動ニューロンは，加齢とともに50%も低下するといわれる．特に，下肢では軸索が長くなって障害を受けやすい．また，筋の増殖に必要な骨格筋組織特異的幹細胞であるサテライト細胞も数が減少することが知られている．食欲の低下や運動不足，性ホルモンの分泌低下，炎症反応の増大などサルコペニアを引き起こす様々な要因が，加齢に伴って増加する[8,9]．

米国での New Mexico 高齢者調査では，70歳

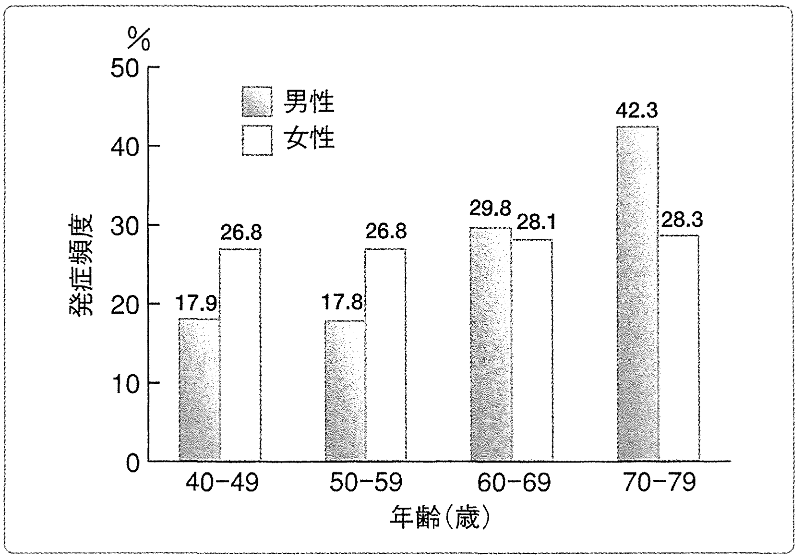


**図3　年齢・性別にみたサルコペニアの頻度**（NILS-LSA）
DXA法により性別の40歳代前半の20パーセンタイル値を基準としてサルコペニアの判定を行った．男性ではCochran-Mantel-Haenszel検定でp trend<0.01であり，年代上昇で割合が有意に上昇していたが，女性では年齢による変化はなかった．

未満では20%程度であるが，80歳以上になると50%以上がサルコペニアとなるとしている[3]．われわれが行っている一般の地域住民を対象とした「国立長寿医療研究センター・老化に関する長期縦断疫学研究（NILS-LSA）」ではDXAによる筋量の測定を実施している．NILS-LSAのデータ解析では，男性で加齢に伴いサルコペニアの頻度が増加するが，女性では少なくとも80歳未満までは，サルコペニアの割合は増加していなかった（図3）．診断基準にもよるが，男女で加齢によるサルコペニアの進行が異なる可能性がある．

## 4．身体活動とサルコペニア

廃用性症候群による筋萎縮は，高齢者のサルコペニアの最大の要因であろう．運動不足による筋量や筋力の低下はどの年代にも起こり得る．しかし，高齢者では筋の再生・増殖機能が低下しており，いったん減少した筋量は回復が難しい．筋量が低下し筋力が低下すれば，運動が困難になり，さらに筋量が低下するという悪循環に陥りやすい．

## 5．性ホルモンとサルコペニア

閉経により内臓脂肪は増加し，骨密度が低下し，筋量および筋力が低下する．一方，エストロゲンの投与はこれらの変化を予防する効果があるとされる．テストステロンの筋増殖効果はよく知られている[10]．高齢男性のテストステロンの低下と筋量，筋力の低下が報告されている．加齢に伴い，性ホルモン結合グロブリン（sex hormone binding globulin：SHBG）が増加し，生体作用を持つ遊離テストステロンが大きく低下する．テストステロンは蛋白質合成を促進する．テストステロンの低下は蛋白質合成能の低下をきたし，筋を萎縮させる．さらに，テストステロンの低下は筋サテライト細胞数の低下を引き起こし，筋の再生・増殖能を低下させるといわれている[11]．

## 6．カロテノイドとサルコペニア

高齢者の筋力低下，身体機能低下はフリーラジカルによる酸化ストレスが原因の一つとなっている可能性が指摘されている．酸化ストレスは骨格筋のDNAを傷つけ，蛋白質や脂質に障害を与える[12,13]．

抗酸化作用を持つカロテノイドが不足すると，高齢者では筋力低下や歩行障害をきたすことが，いくつかの疫学的研究で報告されている．米国のWomen's Health and Aging Studiesでは，年齢，人種，喫煙，心血管性疾患，関節炎，血清インターロイキン-6（interleukin-6：IL-6）を調整して検討したところ，血清総カロテノイドの低下は握力，腰や膝の筋力の低下と有意に関連していた[14]．イタリア，トスカーナ州キャンティ地区の地域在住高齢者での研究でも，βカロテン摂取量が高齢者の膝伸展筋力と相関していた[15]．

NILS-LSAのデータでは血清カロテノイドと体力・運動や日常生活動作（activities of daily living：ADL）との関係が示されている（表2）．外出に不安がある人，階段の昇降や長距離の歩行が困難である人では，血清カロテノイドが低値を示した．一方，筋力や余暇活動時間，1日平均歩数は血清カロテノイドと正の相関を示し，特に日常活動量を示す1日平均歩数はすべての血清カロテノイドで正の関連を示していた．摂取エネルギーで調整したβカロテン摂取量も正の関連を示したことから，単に「元気な人がたくさん食べている」のではなく，多く摂取する人が体力的にも健康であり，また，ADLの低下している人ではカロテノイドが不足している状況が明らかになった．

## 7．ビタミンDとサルコペニア

血中の25-OHビタミンDレベルは，経口摂取あるいは皮膚で産生されたビタミンDの量を反映する指標である．25-OHビタミンDは老化とともに低下することが知られている．ビタミンDはカルシウム代謝に関連するビタミンであり，摂取量の不足は骨粗鬆症などの骨疾患の要因となる．このビタミンDが，筋肉とも関連することが明らかになってきた．

ビタミンD受容体は筋肉中に存在し，ビタミンDが低下することにより筋の同化作用が下がってしまう．また，ビタミンD受容体の遺伝子多型が高齢者のサルコペニアの要因の一つであることも報告されている[16]．ビタミンDの低下が，高齢者の転倒や身体機能障害の要因であるとの報告がある[17,18]．

アムステルダム縦断加齢研究（Longitudinal Aging Study Amsterdam）での3年間の追跡研究では，ベースラインの25-OHビタミンDが低値の場合には，高値の場合に比べて3年後にサルコペニアとなるオッズ比は2.57（95%信頼区間1.40～4.70）であった．このような結果から，ビタミンDの摂取の不足が，高齢者のサルコペニアを引き起こす可能性があると思われる[19]．

## 8．蛋白質，アミノ酸とサルコペニア

筋肉は蛋白質からなっており，蛋白質摂取量，アミノ酸摂取量が低下すれば，筋量は当然低下する．1食当たりの蛋白質量が20～25gである時が筋蛋白質の合成が最も高いとされている[20,21]．食事摂取基準では，健康な70歳以上者に必要な蛋白質量は1.06g/体重(kg)であり，男性60g，女性50g以上が必要とされている．しかし，一般的な高齢者の食事では，この蛋白質摂取量を維持することが難しい場合が多い．

体内で合成できない必須アミノ酸のうち，ロイシン，イソロイシン，バリンは炭素骨格が分岐した構造を持つことから分岐鎖アミノ酸と呼ばれる．これらの分岐鎖アミノ酸は，筋肉を作

表2　血清カロテノイドおよびカロテノイド摂取量と筋力，身体活動との関連（NILS-LSA の結果から）

| | 血清濃度 | | | | | | | | | | | | 平均摂取量 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ルテイン | | リコペン | | αカロテン | | βカロテン | | βクリプトキサンチン | | ゼアキサンチン | | αカロテン | | βカロテン | | βクリプトキサンチン | | βカロテン当量 | |
| | 男性 | 女性 | 男性 | 女性 | 男性 | 女性 | 男性 | 女性 | 男性 | 女性 | 男性 | 女性 | 男性 | 女性 | 男性 | 女性 | 男性 | 女性 | 男性 | 女性 |
| 脚伸展パワー | | | * | * | **** | **** | *** | *** | * | * | | | * | * | | *** | | | | |
| 右膝伸展筋力 | * | * | *** | *** | * | * | *** | *** | | | | | * | * | * | * | | | * | * |
| 左膝伸展筋力 | | | * | * | ** | ** | ** | ** | | | | | | | | | | | | |
| 余暇身体活動量 | *** | *** | *** | *** | * | * | *** | *** | | | *** | *** | ** | ** | | | | | | |
| 2.5METs余暇身体活動量 | *** | *** | | | | | | | | | *** | *** | *** | *** | | ** | * | * | ** | ** |
| 4.5METs余暇身体活動量 | * | * | * | * | | | * | * | | | * | * | | | | | | | | |
| 6.5METs余暇身体活動量 | | | | | | | | | | | | | | | | | | | | |
| 8.5METs余暇身体活動量 | | | | | | | | | | | | | | | | | | | | |
| 1日の平均歩数 | * | * | ** | ** | * | **** | **** | **** | * | * | * | * | | | * | * | | | * | * |

重回帰分析，*：$p<0.05$，**：$p<0.01$，***：$p<0.001$，****：$p<0.0001$，すべて正の関連．
平均摂取量での解析における調整変数：年齢・喫煙・季節差・総摂取エネルギー・BMI（男性），
年齢・閉経・季節差・総摂取エネルギー・BMI（女性）．

る主な蛋白質であるアクチンとミオシンの主成分である．十分な分岐鎖アミノ酸を摂取することで筋肉の消耗を防ぐことができる可能性がある[22,23]．分岐鎖アミノ酸は，肉類，乳製品，レバーなどに多く含まれるが，高齢者ではこうした食品は敬遠されることが多いことも，高齢者のサルコペニアの要因となっている可能性がある．

## おわりに

サルコペニアのスクリーニング指標には確立したものはない．筋量の推定には，現在のところ，インピーダンス法が唯一，スクリーニングとして使用できるが，測定誤差が大きく，実用性に問題がある．上腕最大周囲長など，身体計測によるスクリーニングの方がむしろ実用的かも知れない．さらに，筋力の評価も重要で，そのためには比較的容易に測定できる握力もスク

リーニング指標としては有用であると思われる．

運動不足と低栄養，特に蛋白質摂取の不足，カロテノイドやビタミンＤの不足がサルコペニアの重要な危険因子である．老化による避けがたい生理的な変化もあるが，適度な運動と適切な栄養摂取に心がけることで，筋量や筋力の低下を防ぐことは十分可能であると考えられる．

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ORIGINAL ARTICLE: EPIDEMIOLOGY, CLINICAL PRACTICE AND HEALTH

# Spatiotemporal components of the 3-D gait analysis of community-dwelling middle-aged and elderly Japanese: Age- and sex-related differences

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**Aim:** To describe age- and sex-related differences in gait patterns of community-living men and women using 3-D gait analysis.

**Methods:** Subjects ($n = 2006$) aged 40–84 years participated in the National Institute for Longevity Sciences-Longitudinal Study of Aging (NILS-LSA). Spatiotemporal components, including velocity, step length, step frequency, and double support time during a gait cycle, were calculated from 3-D coordinates and vertical force data. Velocity, step length and step frequency were normalized by leg length and acceleration due to gravity, and double support time was normalized to gait cycle duration.

**Results:** Spatiotemporal walking variables of brisk velocity and step length were significantly greater in men than in women, while comfortable velocity and comfortable and brisk step frequencies and double support times were greater in women than in men. Age-related changes were marked at 70–84 years in most spatiotemporal variables in both sexes during comfortable walking. During brisk walking, age-related changes were observed from a younger age than during comfortable walking, and there were sex-related differences.

**Conclusion:** The age-related gait alteration was obvious among those aged 70 years and older, and it accelerated markedly in women's brisk walking intensity. **Geriatr Gerontol Int 2011; 11: 39–49.**

**Keywords:** aging, gait, sex, velocity, walking.

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Author contributions: W. D. designed the study, obtained the funding, analyzed data and drafted the original article; R. K. interpreted data and advised on revising the article; K. H. Y. supervised data processing and prepared the article; and F. A. and H. S. originated the study, created the gait analysis program, supervised all aspects of its implementations, and contributed to obtaining the funding and revising the article. All authors conducted epidemiological studies on geriatric disease and human aging in Obu, Aichi, Japan, and read and approved the manuscript.

## Introduction

Age-related impairment of ambulatory ability is a critical component for inhibiting activities of daily living (ADL). For instance, decreased gait velocity observed in elderly is an indicator of common distinct diseases[1,2] and falls,[3–6] which lead to functional dependence[7–11] or death.[12] The prevalence and incidence of gait disorders increase with age in elderly persons.[13,14] The early presence of dynamic postural stability may provide more essential information for preserving adequate mobility, delaying the onset of functional decline and encouraging early appropriate lifestyle changes to promote active healthy aging.[6,8,10,11,15]

Previous studies examined age-related changes in spatiotemporal gait parameters including velocity, step length, step frequency (cadence) and selected stride time variables (single and double support time and swing time).[7,8,10,16–21] These performance-based gait variables were often measured by a 3-D gait system that computes the motions of the body center of mass (COM) and each segment, which can accurately evaluate the control of dynamic balance during walking.[22,23] The COM velocity on the 3-D gait system identified the effect of age on older gait in limited comparison between young and older groups.[24–26] It showed that the 3-D analyses conducted have not determined from which age group the accelerated decline of gait started. The collection of data using a large sample size with a broad age range could resolve the issue.

Age-related gait studies have recruited either men or women, or both sexes have been analyzed together: a few studies previously focused on sex-related changes on gait pattern with advancing age. Callisaya *et al.*[8] revealed the effects of sex and age on gait velocity in elderly men and women aged 60–86 years. The results of other studies of various age ranges and groups[17,19,27] to determine which sex shows an earlier age of accelerated gait velocity decrease have differed. The conflicts may partly depend on the sampling and subject characteristics.

Therefore, to understand the aging process in gait measures across the adult lifespan, a large sample size ranging from young or middle-aged to elderly men and women should be warranted. We decided to reinvestigate the previous findings. In the present study, the gait of elderly subjects was investigated based on comfortable and brisk spatiotemporal gait parameters with a 3-D gait analysis system; a large number of subjects were recruited. We found the age-related changes in gait by sex among middle-aged and elderly men and women in Japan. This may contribute to a beneficial effect on assessing gait in elderly people and making an adequate walking exercise program suitable for targeted age groups.

## Methods

### Study sampling

The present gait analysis is part of the third phase of the National Institute for Longevity Sciences Longitudinal Study of Aging (NILS-LSA); this study includes medical, physiological, nutritional and psychological examinations. The study began in November 1997 (the first phase), and the third phase lasted from May 2002 to May 2004. The subjects were age- and sex-stratified random samples of the population, aged 40–84 years, who lived in Obu-shi and Higashiura-cho, Aichi, Japan. These participants were chosen from the residents registered with local governments. All subjects lived or had lived at their home in the community and had Japanese nationality.[28] The NILS-LSA was approved by the Ethics Committee of the National Center for Geriatrics and Gerontology. Details of the NILS-LSA have been previously published.[28,29]

Of 2378 men and women aged 40–84 years in the third phase examination, 1017 men and 989 women (84.2% of all participants, Table 1) completed the walking tests and were included in the present analysis. The participants also completed a structured questionnaire dealing with their socioeconomic characteristics, cardiovascular risk factors and medical history.[28,29] Exclusion criteria included a current medical history of arthritis[6,8] and fractures (musculoskeletal disorders),[30] stroke[1] and Parkinson's disease (neurological disorders),[8,31] and ischemic heart disease and chronic bronchitis (Table 1).[32,33] These diseases were checked and excluded as the possible cause of gait disorders or spatiotemporal gait parameter changes by a physician before the walking tests. One participant who was diagnosed with dementia was excluded because she had a limited ability to comprehend or execute the test, which was judged by a physician. The existence of walking difficulty in activities of daily living (ADL)[11,15] was also excluded (Table 1). The participants who met the above-mentioned requirements and could walk 10 m independently without a walking aid were included in the current gait analysis and therefore 372 participants of the third phase examination were totally excluded.

### Protocol

All participants wore short-sleeved T-shirts and shorts for testing. Shoes were made from the same material that had a vinylon/polyester and cotton blended upper part and a urethane foam outsole (Moonstar, Fukuoka, Japan), and were selected to exactly fit each participant's feet. Ten 2.5-cm diameter optical markers were placed on the participants' left and right sides on the fifth metatarsal heads, the lateral malleoli, the lateral epicondyles, and one-third of the way along the straight lines from the greater trochanters to the anterior

**Table 1** Inclusion/exclusion characteristics of 2378 participants in the third wave examination of the National Institute for Longevity Sciences-Longitudinal Study of Aging (NILS-LSA), 2002–2004

| Characteristics | Men | Women |
|---|---|---|
| Inclusion ($n = 2006$) | | |
| Total ($n$ (%)) | 1017 (50.7) | 989 (49.3) |
| Age group ($n$ (%))† | | |
| 40s | 250 (12.5) | 279 (13.9) |
| 50s | 302 (15.1) | 265 (13.2) |
| 60s | 250 (12.5) | 242 (12.1) |
| ≥70 | 215 (10.7) | 203 (10.1) |
| Exclusion ($n = 372$) | | |
| Total ($n$ (%)) | 187 (50.3) | 185 (49.7) |
| Prevalence of disease ($n$ (%)) | | |
| Stroke | 42 (22.5) | 23 (12.4) |
| Ischemic heart disease | 41 (21.9) | 41 (22.2) |
| Chronic bronchitis | 7 (3.7) | 3 (1.6) |
| Arthritis | 26 (13.9) | 56 (30.3) |
| Fracture | 5 (2.7) | 6 (3.2) |
| Dementia | – | 1 (0.5) |
| Parkinson's disease | 3 (1.6) | – |
| Walking difficulties in ADL ($n$ (%)) | 50 (26.7) | 54 (29.2) |
| Not completed walking test ($n$ (%)) | 55 (29.4) | 53 (28.6) |

†$\chi^2$-Test test examines significance among each age group and sex. Values are numbers (% of total at each inclusion/exclusion category) of samples. ADL, activities of daily living.

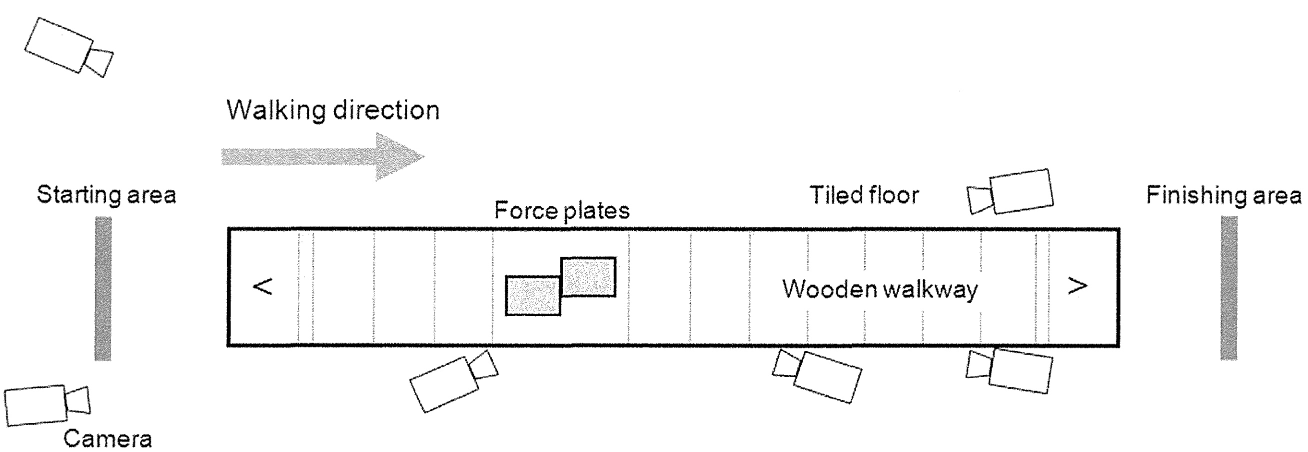


**Figure 1** Setup of 3-D gait system: the 10-m walkway consisted of a wooden walkway. Six cameras were placed at various positions and two force platforms were embedded in the center of the walkway. Double support time in pre-swing phase of right foot was measured in this setting.

superior iliac spines and the acromions.[34] The subjects walked on a 10-m walkway at two speeds: (i) at a self-selected pace (comfortable walking); and (ii) as fast as possible without running (brisk walking). Each pace was repeated approximately twice on average. The walkway consisted of a tiled floor and a wooden walkway along the corridor (Fig. 1). The surface of the wooden walkway was covered with gray-colored, thin, stiff rubber, which measured 0.036 m in height from the tile floor surface of the corridor. Force platforms (0.6 m × 0.4 m) (9286; Kistler Instrumente AG, Winterthur, Switzerland), with surface colors similar to those of the walkways, were embedded in the center of the wooden walkway. The starting point for each trial was

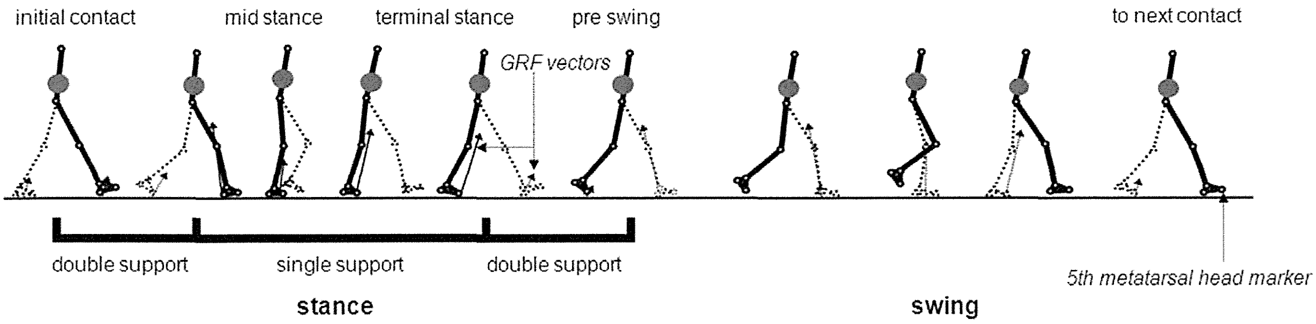


**Figure 2** Definition of gait cycle using ground reaction force (GRF) and the fifth metatarsal head marker.

selected in relation to the foot contacts on the force platforms. The distance from each starting and departure point to the force platforms was approximately 3.5–4.5 m. One trial each of comfortable and brisk walking was used in the data analysis. The trials used were those that lacked the least data.

The Vicon 370 system (Oxford Metrics Ltd, Oxford, UK), which consisted of six cameras, was used to obtain the 3-D coordinates of the trunk, thighs, shins and feet. The calibration residual at each camera was set below 1.0 mm. The data were processed using a custom routine that was programmed by the Clinical Gait Analysis Forum of Japan.[34] The raw coordinate data at 60 Hz were digitally filtered with a fourth-order, zero-lag, Butterworth filter[22] with a cut-off at 5 Hz, and the raw ground reaction force data at 1200 Hz were digitally filtered with a cut-off at 10 Hz. The force data were interpolated to correspond with the coordinate data to synchronize the datasets. Smoothed coordinates of the lower extremities were used to construct a rigid link-segment model.[22] Segment masses and inertial properties were determined using previously reports[35] and the participants' mass and height, which were used for calculating COM.

### *Gait cycle and walking variable calculation*

SAS ver. 9.1.3.[36] was used to automatically identify gait event times and each phase of the gait cycle based on kinematic and kinetic gait data. The divisions of the gait cycle are shown in Figure 2.[30] The gait event times for initial contacts and toe off were determined using vertical force data and the vertical motion of the optical marker on the fifth metatarsal head. The period from the first right initial contact to ipsilateral second initial contact was one gait cycle.[30]

Both the right and left leg motions were captured, and primarily the right stride was analyzed. Left leg motion was used for calculating the step length and double support times. The mean COM velocities, step lengths, step frequencies and double support times during a gait cycle were also automatically computed by SAS. The double support time was defined as the duration of time during which each foot was on the ground in the pre-swing phase. The mean COM velocity, step length, and step frequency were normalized as proposed by Hof[37] as follows:

Normalized COM velocity, $\hat{v} = \frac{v}{\sqrt{gl_0}}$,

Normalized step length, $\hat{l} = \frac{l}{l_0}$,

Normalized step frequency, $\hat{f} = \frac{f}{\sqrt{g/l_0}}$,

where $v$ is actual mean COM velocity, $l_0$ is the leg length of each subject, $l$ is the actual step length, $f$ is the actual step frequency and $g$ is the acceleration due to gravity (9.81 m/s$^2$). Leg length was measured from the ground to the greater trochanter during quiet standing. Patients with arthritis and fracture were excluded (Table 1), and no case of limited knee extension was observed in the present study. The double support time was also normalized by each subject's cycle duration, from right initial contact to next right initial contact (over one gait cycle).

For the calculation of walking variables, technical difficulties sometimes caused missing data due to the effect of occlusion while capturing motion. Thus, for example, the mean COM velocity over the gait cycle was calculated using data from 1716 men and women (85.5% of the total sample) during comfortable walking and using data from 1614 men and women during brisk walking (80.4%). To demonstrate the lack (or presence) of bias with respect to velocity data loss, the Student's $t$-test was used to compare the velocity between the group with all available data and that with data available only in the velocity category. The results showed that the velocities were not significantly different between the two groups, and this was confirmed for all walking variables.

### *Statistical analyses*

All analyses were performed using SAS ver. 9.1.3. Sex differences were examined using the Student's $t$-test. For analysis of age differences, participants were divided into eight groups based on sex and age (40–49, 50–59, 60–69 and 70–84 years for each sex). Trends in differences across all age groups in the walking variables were tested using the General Linear Model (GLM), and differences by age group were tested using the Tukey–Kramer method for each sex. $P < 0.05$ was considered statistically significant.

## Results

The proportion of the sample drawn from each age group and each sex group was the same ($\chi^2$-test, $P > 0.05$). The mean ± standard deviation age was 58.1 ± 11.4 years in men and 58.7 ± 11.4 years in women, which was not significant ($P > 0.05$).

The results of the GLM and Tukey–Kramer tests revealed age-related changes in each age and sex group. Descriptive statistics for all values are shown in Tables 2 and 3 and Figure 3. Mean COM velocities during comfortable and brisk walking significantly decreased with age in both sexes ($P < 0.001$). Age-related changes in the comfortable COM velocity were marked in the 70–84-year group compared with other age groups. Similar changes were found in the brisk COM velocity. The step lengths and frequencies followed these COM velocity patterns in both sexes during both comfortable and brisk walking.

These age-related changes occurred earlier in the middle-aged group. Earlier patterns involving brisk gait parameters were more apparent in women: for example, the brisk COM velocity decreased at 60–69 years in men and at 50–59 years in women, then the decrease accelerated at 70–84 years (Tables 2,3, Fig. 3). The step length and frequency followed these COM velocity patterns. The double support time during pre-swing was significantly increased with age only at the women's comfortable walking pace; it was significantly longer in the 70–84-year group compared to other age groups (Table 3, Fig. 3). The men's double support times showed no significant age-related differences among age groups ($P$ for trend >0.05, Fig. 3).

Descriptive statistics and the results of sex differences for gait parameters are depicted in Table 4. The results of mean COM velocity differed according to walking pace: the comfortable COM velocity was significantly faster in women than in men ($P < 0.001$), and the brisk COM velocity was significantly faster in men than in women. Step length pattern was similar to COM velocity pattern: the brisk step length was longer in men than in women ($P < 0.001$), but the comfortable step length was not significantly different. On the other hand, women had a higher step frequency during both walking paces ($P < 0.001$). The results of the pre-swing double support time were equal to the step frequency.

## Discussion

Mobility is essential for independence in the elderly. A better understanding of age-related changes in gait provides useful information for appropriate intervention programs targeting specific age groups.[8] The present cross-sectional, descriptive study showed spatiotemporal components of gait over one gait cycle among community-living middle-aged and elderly Japanese subjects. The sample of 1017 men and 989 women was large enough to allow analysis by age group,[17] and, to the best of our knowledge, the sample size is the largest to be published in which gait characteristics have been analyzed using a 3-D gait system. There was no disproportionate lack of gait data caused by difficulties in capturing the 3-D coordinates.

Mean COM velocities decreased with age, which is in almost complete agreement with previous results, despite the use of different measurement equipment and instrumentation.[16–21,25,29] The age-related decreases in the normalized COM velocities accelerated at 70 years and over were noted at a relatively later age compared with the previous reports: they showed the accelerated decline occurred in 50–59- and 60–69-year age groups,[17] at 62 years,[19] between 60- and 70-year age groups,[20] and at 65 years and in the 67–73-year age group.[18] The differences in age of accelerated decline among the previous and the present findings were likely due to the differences in method and data characteristics.

The brisk COM velocity decreases advancing with age were earlier compared with the comfortable walking. Some previous studies showed the age-related decrease was independent of walking pace,[18–20] while another reported that the decrease depended on the pace.[7] In a report by Bohannon on the comfortable and maximum walking speeds of adults aged 20–79 years,[7] walking speed was found to be influenced by the interaction of pace and age. This result matched our present findings that the age-related decrease was clearer during brisk walking than during comfortable walking. Moreover, these earlier age-related declines in the brisk COM velocities were apparent in women. Some studies reported that the critical age for marked velocity decrease did not differ by sex,[16,19] while another found the critical age to be earlier in men.[17] However, Callisaya *et al.*[8] showed women's walking velocity to be an earlier age-related change compared to men's parameters during the preferred speed of walking among the subjects aged 60 years and older. These results are in agreement with our own, though our data was particularly strong in the brisk parameters across middle-aged and elderly persons. The brisk walking task required greater forward momentum and increased demands in muscle activity[24,38–40] and aerobic capacity[33,41] might alter the spatiotemporal gait parameters accompanying aging.

**Table 2** Men's normalized mean COM velocities, step lengths and frequencies and double support times during comfortable and brisk walking in each age group

| Men: walking parameters by age group | Mean COM velocity | | | | Step length | | | | Step frequency | | | | Double support times (pre-swing) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | Mean | SD | 95% CI | N | Mean | SD | 95% CI | N | Mean | SD | 95% CI | N | Mean | SD | 95% CI |
| Comfortable walking | | | | | | | | | | | | | | | | |
| 40s | 211 | 0.524 | 0.053 | 0.517–0.531 | 240 | 0.892 | 0.065 | 0.884–0.900 | 207 | 0.587 | 0.043 | 0.582–0.593 | 208 | 14.8 | 1.5 | 14.6–15.0 |
| 50s | 266 | 0.527 | 0.059 | 0.520–0.534 | 289 | 0.897 | 0.076 | 0.888–0.906 | 259 | 0.590 | 0.042 | 0.585–0.595 | 249 | 14.8 | 1.5 | 14.6–14.9 |
| 60s | 218 | 0.523 | 0.067 | 0.514–0.532 | 240 | 0.901 | 0.089 | 0.890–0.913 | 215 | 0.583 | 0.046 | 0.577–0.589 | 205 | 14.5 | 1.6 | 14.3–14.7 |
| 70– | 186 | 0.485 | 0.070 | 0.475–0.495 | 213 | 0.859 | 0.096 | 0.846–0.872 | 185 | 0.569 | 0.047 | 0.562–0.576 | 177 | 15.2 | 2.0 | 14.9–15.5 |
| *P* for trend[†] | <0.001 | | | | <0.001 | | | | <0.001 | | | | NS | | | |
| (Tukey–Kramer test)[‡] | 40s, 50s, 60s >70– | | | | 40s, 50s, 60s >70– | | | | 40s, 50s, 60s >70– | | | | NA | | | |
| Brisk walking | | | | | | | | | | | | | | | | |
| 40s | 190 | 0.705 | 0.078 | 0.694–0.716 | 229 | 0.998 | 0.074 | 0.989–1.008 | 180 | 0.707 | 0.070 | 0.696–0.717 | 173 | 13.3 | 6.0 | 12.4–14.2 |
| 50s | 235 | 0.699 | 0.082 | 0.688–0.709 | 272 | 0.998 | 0.088 | 0.987–1.008 | 214 | 0.697 | 0.064 | 0.688–0.705 | 209 | 13.3 | 5.6 | 12.6–14.1 |
| 60s | 191 | 0.678 | 0.079 | 0.667–0.690 | 237 | 1.000 | 0.094 | 0.988–1.012 | 185 | 0.685 | 0.066 | 0.676–0.695 | 180 | 13.4 | 5.0 | 12.6–14.1 |
| 70– | 182 | 0.618 | 0.092 | 0.605–0.631 | 203 | 0.946 | 0.100 | 0.932–0.960 | 177 | 0.657 | 0.066 | 0.647–0.667 | 169 | 14.1 | 2.1 | 13.8–14.4 |
| *P* for trend[†] | <0.001 | | | | <0.001 | | | | <0.001 | | | | NS | | | |
| (Tukey–Kramer test)[‡] | 40s > 60s > 70–., 50s > 70– | | | | 40s, 50s, 60s >70– | | | | 40s > 60s > 70–., 50s > 70– | | | | NA | | | |

[†]Trend tests examine main effects of age in each gait parameter. [‡]Tukey–Kramer tests examine the significant difference among each age group. '>' indicates the significant difference between the age groups, with *P*-value is less than 0.5. Values are numbers of samples (N), means (Mean), standard deviations (SD) and 95% confidence intervals (95% CI) at each variable. Age group: 40s, 40–49 years age group; 50s, 50–59 years age group; 60s, 60–69 years age group; 70–, 70–84 years age group. COM, center of mass; NS, not significant; NA, not applicable.

**Table 3** Women's normalized mean COM velocities, step lengths and frequencies and double support times during comfortable and brisk walking in each age group

| Women: walking parameters by age group | Mean COM velocity | | | | Step length | | | | Step frequency | | | | Double support times (pre-swing) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | Mean | SD | 95% CI | N | Mean | SD | 95% CI | N | Mean | SD | 95% CI | N | Mean | SD | 95% CI |
| Comfortable walking | | | | | | | | | | | | | | | | |
| 40s | 228 | 0.542 | 0.060 | 0.535–0.550 | 267 | 0.905 | 0.072 | 0.896–0.913 | 223 | 0.602 | 0.044 | 0.596–0.608 | 212 | 14.9 | 1.7 | 14.7–15.2 |
| 50s | 224 | 0.547 | 0.066 | 0.538–0.556 | 252 | 0.902 | 0.082 | 0.891–0.912 | 219 | 0.607 | 0.051 | 0.600–0.614 | 214 | 14.9 | 1.7 | 14.7–15.1 |
| 60s | 210 | 0.536 | 0.064 | 0.527–0.544 | 236 | 0.890 | 0.079 | 0.880–0.900 | 207 | 0.602 | 0.045 | 0.596–0.608 | 189 | 15.0 | 1.9 | 14.8–15.3 |
| 70– | 173 | 0.472 | 0.071 | 0.461–0.483 | 189 | 0.833 | 0.093 | 0.820–0.847 | 169 | 0.570 | 0.051 | 0.562–0.578 | 148 | 15.8 | 1.9 | 15.5–16.1 |
| *P* for trend† | <0.001 | | | | <0.001 | | | | <0.001 | | | | <0.001 | | | |
| (Tukey–Kramer test)‡ | 40s, 50s, 60s >70– | | | | 40s, 50s, 60s >70– | | | | 40s, 50s, 60s >70– | | | | 70– > 60s, 50s, 40s | | | |
| Brisk walking | | | | | | | | | | | | | | | | |
| 40s | 216 | 0.702 | 0.072 | 0.692–0.711 | 269 | 0.972 | 0.070 | 0.963–0.980 | 210 | 0.728 | 0.071 | 0.719–0.738 | 201 | 13.9 | 1.6 | 13.7–14.2 |
| 50s | 215 | 0.675 | 0.080 | 0.665–0.686 | 252 | 0.960 | 0.087 | 0.950–0.971 | 212 | 0.706 | 0.073 | 0.696–0.715 | 209 | 14.2 | 1.7 | 13.9–14.4 |
| 60s | 212 | 0.653 | 0.072 | 0.643–0.662 | 230 | 0.941 | 0.085 | 0.929–0.952 | 209 | 0.696 | 0.072 | 0.687–0.706 | 199 | 14.2 | 1.8 | 14.0–14.5 |
| 70– | 173 | 0.577 | 0.084 | 0.565–0.590 | 187 | 0.890 | 0.109 | 0.875–0.906 | 163 | 0.651 | 0.064 | 0.562–0.578 | 157 | 14.3 | 8.8 | 12.9–15.7 |
| *P* for trend† | <0.001 | | | | <0.001 | | | | <0.001 | | | | NS | | | |
| (Tukey–Kramer test)‡ | 40s > 50s > 60s > 70– | | | | 40s > 60s > 70–., 50s > 70– | | | | 40s > 50s, 60s > 70– | | | | NA | | | |

†Trend tests examine main effects of age in each gait parameter. ‡Tukey–Kramer tests examine the significant difference among each age group. '>' indicates the significant difference between the age groups, with $P < 0.05$. Values are numbers of samples (N), means, standard deviations (SD) and 95% confidence intervals (95% CI) at each variable. Age group: 40s, 40–49 years age group; 50s, 50–59 years age group; 60s, 60–69 years age group; 70–, 70–84 years age group. COM, center of mass; NS, not significant; NA, not applicable.

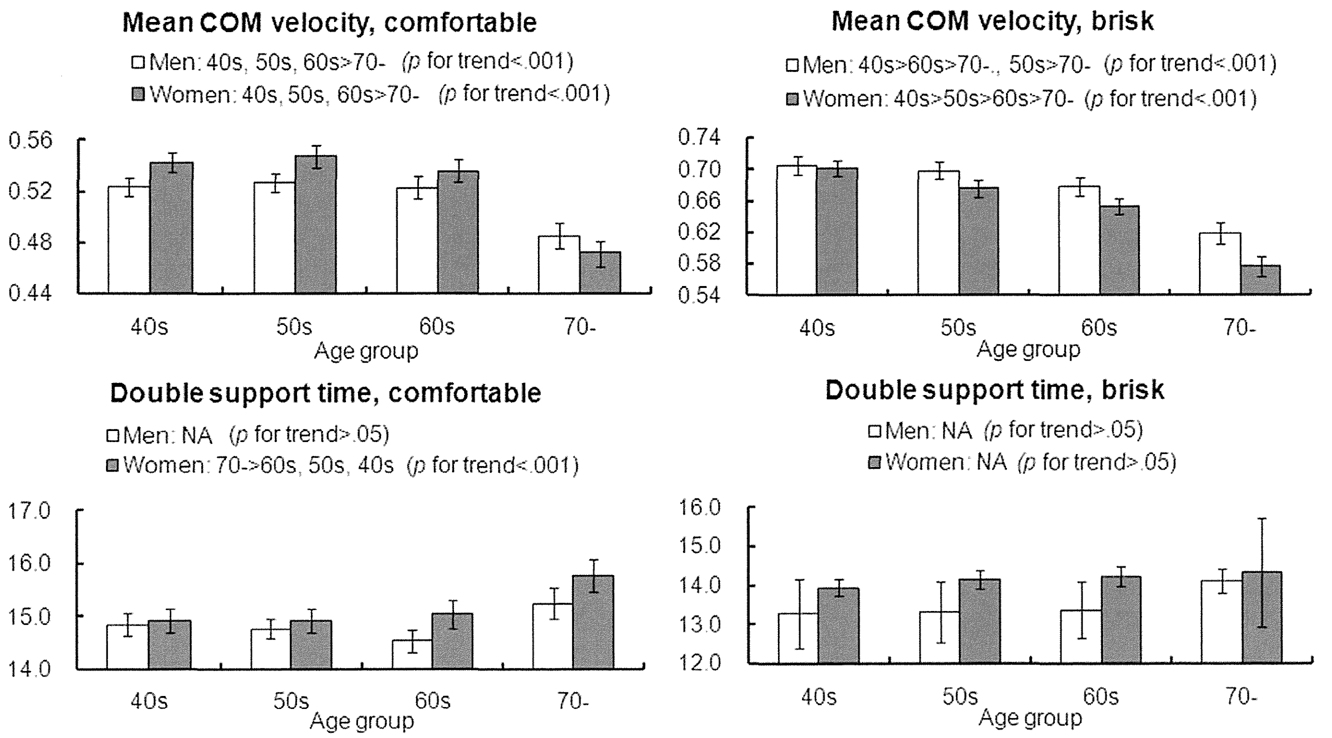


**Figure 3** Age-related differences (trend tests and Tukey–Kramer tests); means and 95% confidence intervals of normalized mean center of mass (COM) velocities ($(\mathrm{m/sec})/\sqrt{((\mathrm{m/sec}^2)\times \mathrm{m})}$) and double support times (s/s) during comfortable and brisk walking in men and women. Significant differences by age group in men and women are noted on the upper side of each figure. '>' indicates the significant difference between the age groups, with *P*-values of ≤0.05.

**Table 4** Normalized mean COM velocities, step lengths and frequencies and double support times during comfortable and brisk walking among men and women

| Walking parameters | Men | | | | Women | | | | *P*-value† |
|---|---|---|---|---|---|---|---|---|---|
| | N | Mean | SD | 95% CI | N | Mean | SD | 95% CI | |
| Comfortable walking | | | | | | | | | |
| Mean COM velocity | 881 | 0.516 | 0.064 | 0.512–0.521 | 835 | 0.527 | 0.071 | 0.523–0.532 | <0.001 |
| Step length | 982 | 0.889 | 0.083 | 0.883–0.894 | 944 | 0.886 | 0.085 | 0.881–0.891 | NS |
| Step frequency | 866 | 0.583 | 0.069 | 0.580–0.586 | 818 | 0.597 | 0.045 | 0.593–0.600 | <0.001 |
| Double support time (pre-swing) | 839 | 14.8 | 1.7 | 14.7–14.9 | 763 | 15.1 | 1.8 | 15.0–15.2 | <0.001 |
| Brisk walking | | | | | | | | | |
| Mean COM velocity | 798 | 0.677 | 0.089 | 0.671–0.683 | 816 | 0.656 | 0.089 | 0.650–0.662 | <0.001 |
| Step length | 941 | 0.987 | 0.092 | 0.981–0.993 | 938 | 0.945 | 0.092 | 0.939–0.951 | <0.001 |
| Step frequency | 756 | 0.687 | 0.075 | 0.682–0.692 | 794 | 0.698 | 0.049 | 0.693–0.703 | <0.001 |
| Double support time (pre-swing) | 731 | 13.5 | 5.0 | 13.2–13.9 | 766 | 14.2 | 4.3 | 13.9–14.5 | <0.01 |

†Student *t*-tests examine the sex differences. Values are numbers of samples (N), means, standard deviations (SD) and 95% confidence intervals (95% CI) at each variable. COM, center of mass; NS, not significant.

Further investigation should have discussed the difference between comfortable and brisk walking parameters.[38,42,43]

Age-related step length decreases during comfortable and brisk walking were almost concomitant with the COM velocity decreases, which was similar to the previous findings.[16,20] In brisk walking, however, age-related reduction in the step length seemed to be smaller than that in the step frequency compared with comfortable walking. For example, women's brisk step length decrease was 8.4% across middle-aged and elderly groups compared with their step frequency decrease of 10.7% (Table 3). This was observed also in men's. This may suggest that ambulatory ability observed in the COM velocity may be caused more by the step length during comfortable walking and the step frequency during brisk walking in the elderly. This was also apparent in middle-aged women. The interpretation was limited qualitatively and should be further explored.

Step frequencies also decreased with age and this decrease was found even in middle-aged women during brisk walking. Previous studies in step frequency reported no age-related changes,[16,17,21] age-related decrease[8,18–20,25] and age-related increase.[26] Moreover, the current age- and sex-related decrease depending on required walking pace was not previously reported.[16,17] One explanation of these conflicts was that degree of the age-related reduction in step frequency was relatively less than that in other gait parameters such as velocity or step length.[8,17,19,20] Therefore, sample size, subject characteristics and measuring instruments may affect the age-related decrease in the step frequency.[16,25] Double support times in the present study did not increase with age, with the exception of women's comfortable data. On the other hand, exploratory analyses of actual values of double support times showed age-related increases in both sexes during both walking paces (data not shown, $P$ for trend <0.001, <0.022). This shows that the double support as a percentage of one gait cycle remained almost constant in middle-aged and elderly subjects. Ferrandez *et al.*[32] found that double support time increased as velocity decreased, and that prolonged double support time was affected more by walking velocity than age.

The present study found brisk COM velocity and step length to be greater in men than in women. By contrast, step frequencies and double support times were greater in women than in men. This is characteristic of sex differences and is supported by previous findings.[8,17,21] Although the comfortable COM velocity was faster in women than in men, this is believed to be a result of the difference in body size as the actual comfortable COM velocity was significantly faster in men than in women (men, $1.46 \pm 0.18$ m/s; women, $1.43 \pm 0.20$ m/s; $P < 0.001$). The comfortable step length did not differ significantly between either sex group, perhaps because of the slower men's COM velocity.

The present gait data may give some insight into gait assessment and preventive walking exercise programs for older persons as previously reported.[42,44,45] The values for the gait parameters during one gait cycle may be useful to clinicians judging the ambulatory ability of patients from a short indoor walk.[7,42] Patients whose gait parameters are lower than that of their appropriate age group are at increased risk of ADL difficulties.[8,11] Comfortable and brisk walking velocities are predictive of adverse outcomes such as loss of physical function, requirement of caregivers, hospitalization and increased mortality in elderly persons.[8,10–12] Decreased step length and prolonged double support time are correlated with fear of falling and/or future fall risk.[4,5,9] Also, the other gait parameters such as gait velocity,[9,11] stride-to-stride variability[4] and lateral sway[3,5,6,46] are associated with the falling events. We did not directly ascertain whether the participants had a history of falls and/or a fear of falling in our gait parameters. Further work should confirm which gait measure is the best independent predictor for future fall risk in a large sample.

A moderate workload prescription in walking exercise programs should be given by controlling both step length and step frequency during comfortable walking in the elderly. Brisk walking, which is recommended for moderately vigorous endurance training and has a high impact compared to comfortable pace walking, might be considered for middle-aged women and the elderly to improve physical functions such as muscle strength[7,40,43] and/or cardiovascular fitness.[33,41]

This study has some limitations. Some previous gait investigations used the results of several trials or mean values of gait, while we used gait data from one trial of each participant. This was done because of technical difficulties in the automatically computed 3-D gait parameters. Next, the conjunction of our excluding criteria with the potential diseases might overestimate gait disorders: the elderly subjects were more likely to be healthy and physically fit. Moreover, patients with dementia were considered to be less in the present sample. The general comparability of the present gait variables with previously reported data is limited because of the lack of data for young adults in their 20s and 30s. Furthermore, our cross-sectional analysis approach could not demonstrate a cause-and-effect relationship from aging. We are planning longitudinal studies to further determine the effects of aging on gait. The present study included regional limitations such as race, culture, lifestyle, genetics and socioeconomic status which also may be important. However, the findings did permit age- and sex-related differences in gait to be clarified in the elderly.

In conclusion, age- and sex-related gait alterations were apparent in one gait cycle of walking in a large sample of community-dwelling, middle-aged and elderly Japanese men and women, when analyzed by a 3-D gait system. There were marked age-related gait differences in subjects aged 70 years and over compared to subjects aged 40–69 years during comfortable walking, and subtle differences were also observed in subjects aged 40–69 years during brisk walking. The earlier age-related changes were clearer in women than in men. These results may guide the assessment of gait patterns attributed to usual aging and to develop moderate exercise programs for the elderly.

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# 運動器疾患の長期縦断疫学研究

Longitudinal epidemiological study on locomotive organ disease

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◎運動器症候群の予防方法を解明するためには，その危険因子を明らかにすることが必要である．一般住民を対象とした長期縦断疫学研究により，運動器疾患罹患の実態を明らかにするとともに，栄養や運動，疾病罹患，飲酒や喫煙などの生活習慣，遺伝的素因などと加齢にかかわる運動器疾患の発症との関連を解明することができる．国立長寿医療研究センターでは無作為抽出された一般地域住民を対象に，老化・老年病に関する基礎データの収集のための長期にわたる集団の大規模な縦断研究「老化に関する長期縦断疫学研究(NILS-LSA)」を平成9年度(1997)より行っている．NILS-LSAでの調査から，日本人全体で骨粗鬆症は1,000万人，変形性膝関節症は3,000万人を超える患者がいると推計された．現在，遺伝子や生活習慣，体力，栄養などさまざまな要因についての縦断的な解析から高齢者の運動器疾患のリスク要因を明らかにし，予防方法を開発するための研究を行っている．

Key word：長期縦断疫学，老化，骨粗鬆症，変形性関節症

運動器症候群(ロコモティブシンドローム)とは，運動器の障害により要介護になるリスクの高い状態になることである．実際に要介護となる要因として関節疾患，転倒・骨折が大きな割合を占めている．高齢者における関節疾患のほとんどは変形性関節症であり，また高齢者の骨折は骨粗鬆症がおもな要因となっている．変形性関節症と骨粗鬆症に限っても，運動器症候群の推計患者数は4,700万人(男性2,100万人，女性2,600万人)に達するという[1]．日本社会の高齢化に伴って，今後さらに急速にこれらの患者数は増大していくものと推定されている．また，運動器症候群は認知症の要因となるとも考えられており，運動器症候群の予防に関する研究は，日本において今後の進展が強く望まれる分野である[2]．

運動器症候群の予防方法を解明するためには，その危険因子を明らかにすることが必要である．無作為抽出された一般住民を対象とした長期にわたる観察研究は，一般住民の間での運動器疾患罹患の実態を明らかにするとともに，栄養や運動，疾病罹患，飲酒や喫煙などの生活習慣，遺伝的素因などと加齢にかかわる運動器疾患の発症との関連を解明するために不可欠である．こうした研究により，どのような素因をもち生活を送っている人が，どのような確率で運動器疾患に罹患していくのか，どのように対策を取れば，どのくらいの確率で予防できるのかを明らかにすることができる[2]．

## 長期縦断疫学研究

国立長寿医療研究センターでは老化・老年病に関する基礎データの収集のために長期にわたる集団の大規模な縦断研究「老化に関する長期縦断疫学研究(NILS-LSA)」を平成9年度(1997)より行っている(図1)[3-7]．対象は地域住民から年齢・性別に層化し無作為抽出された，観察開始年齢が40〜79歳の男女である．抽出によって選定された人を説明会に招いて，検査の目的や方法などを十分に説明し，インフォームドコンセントを得たうえで検査を実施している．追跡中のドロップアウ