Table 4 Partial correlation coefficients, with Mini-Mental State examination and depression as the control variable, between parameters related to quadriceps muscle strength and Tokyo Metropolitan Institute of Gerontology instrumental activities of daily living score

	Sex	Parameter	Partial correlation coefficient	Statistical significance
All participants	Male (n = 234)	KES	0.009	NS
		KET	0.018	NS
		WA-KES	0.066	NS
		WA-KET	0.071	NS
	Female (n = 913)	KES	0.091	‡
		KET	0.091	‡
		WA-KES	0.085	†
		WA-KET	0.090	‡
Subgroup of TMIG-IADL ≥ 4	Male (n = 229)	KES	−0.017	NS
		KET	−0.011	NS
		WA-KES	0.014	NS
		WA-KET	0.017	NS
	Female (n = 879)	KES	0.088	‡
		KET	0.078	†
		WA-KES	0.115	‡
		WA-KET	0.108	‡

†$P < 0.05$, ‡$P < 0.01$. KES, knee extension strength; KET, knee extension torque; WA-KES, weight-adjusted knee extension strength; WA-KET, weight-adjusted knee extension torque.

included only those with TMIG-IADL scores of 4–5 (R 0.100–0.133; $P < 0.005$) (Table 3).

Using the MMSE and MINI as the controlling variables, all the partial correlations between the quadriceps muscle strength parameters and the TMIG-IADL score in men were statistically non-significant (Table 4). In women, all the partial correlations were weak (R 0.085–0.091), but statistically significant ($P < 0.05$; Table 4). These partial correlations for women remained significant even when analysis included only those with TMIG-IADL scores of 4–5 (R 0.078–0.115; $P < 0.05$) (Table 4).

Analysis of the ratio of IADL disability to KE strength

Male participants were classified by KE strength quintiles into the following five categories: very low, KE strength <229 N; low, KE strength 229–267 N; normal, 267–311 N; high, 311–355 N; and very high, KE strength >355N. The χ^2-test showed that IADL disability was independent of KE strength (Pearson's χ^2, 5.199; df, 4; $P = 0.267$) in men. The occurrence of IADL disability showed no trend related to KE strength (Cochran–Armitage test, $P = 0.828$) (Fig. 1). These results were also true for the subgroup of men whose TMIG-IADL scores were between 4 and 5.

Female participants were classified by KE strength quintiles into the following five categories: very low, KE strength <159 N; low, KE strength 159–192 N; normal, KE strength 192–221 N; high, KE strength 221–254 N; and very high, KE strength >254 N. IADL disability was dependent of KE strength (Pearson's χ^2, 23.685; df, 4; $P < 0.0005$). The occurrence of IADL disability decreased as KE strength increased; the percentage of participants with IADL disability was 12.9%, 6.5%, 6.3%, 4.3% and 1.1% for the grades very low, low, normal, high, and very high, respectively (Fig. 1), and this inverse trend was statistically significant (Cochran–Armitage test, $P < 0.0005$). These results were also true for the subgroup with TMIG-IADL scores between 4 and 5 (Pearson's χ^2, 11.811; df, 4; $P = 0.019$; Cochran–Armitage test, $P = 0.019$).

Discussion

The present study examined the relationship between KE strength and IADL in older adults living in a local area of Tokyo. In contrast to the study by Azegami *et al.*, the present results suggest that single-joint–task KE strength is significantly related to IADL in women.[6] In women, every KE strength parameter correlated with IADL. As partial correlations adjusted by cognitive function and depressive scale were also present, it is suggested that KE strength affects IADL independently. In women, KE strength was related to the prevalence of IADL disability. In men, no correlation between KE strength and IADL was observed. These results were the

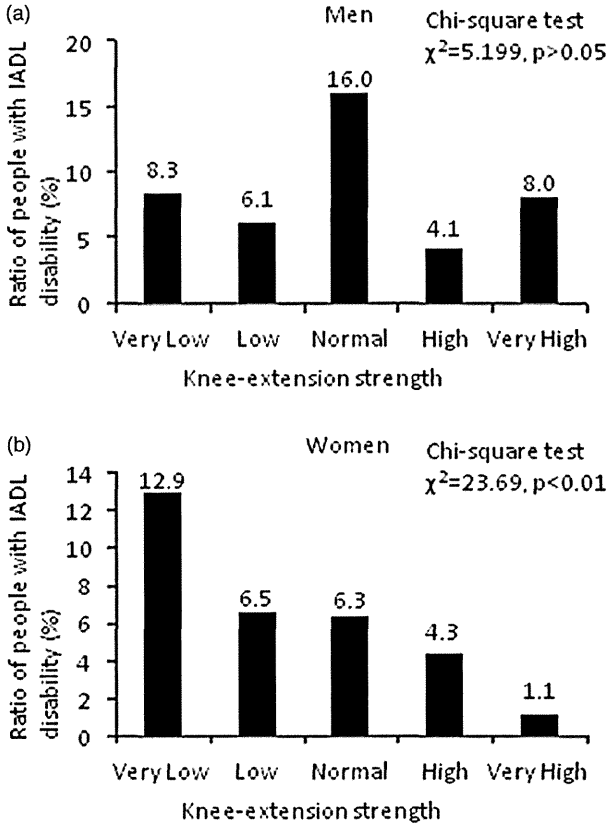

Figure 1 Prevalence of in instrumental activities of daily living (IADL) disability in relation to knee-extension strength (KES) in (a) men and (b) women. KES, men: very low, <229 N; low, 229–267 N; normal, 267–311 N; high, 311–355 N; very high, >355 N. KES, women: very low, <159 N; low, 159–192 N; normal, 192–221 N; high, 221–254 N; very high, >254 N. IADL, instrumental activities of daily living; KES, knee-extension strength.

same even when the subject population was limited to those who had relatively high TMIG-IADL scores (≥4).

Basic ADL has been reported to be affected by the knee extension strength; participants whose strength test scores were in the lowest tertile had two- to three-fold the risk of ADL dependence than those in the highest tertile.[15] Therefore, the present result for men, suggesting no relationship between KE strength and the degree of IADL disability, seems counterintuitive.

To determine whether any one question specifically affected the sex-based differences, we carried out Pearson's χ^2-tests to assess the relationship between KE strength and the answer to each specific question (Q1–Q5). This result showed that, in women, the KE strength and answers to specific questions were related for all items except Q3, with a same trend as total IADL. In men, KE strength and the responses to every specific question were independent. This result suggests that the sex-based difference was not due to any particular item.

One possible explanation for the lack of such a relationship in men is that men had a generally higher KE strength than women. The muscular strength threshold required to carry out IADL independently is 2.8 N/kg (force divided by bodyweight) in the Japanese elderly population.[16] A total of 95% of our male and 92% of female participants had a KE strength above this threshold. This suggests that based on KE strength, more men were able to carry out IADL independently than women. This factor could partly explain the lack of correlation in men.

Another possible explanation for the lack of a correlation between KE strength and IADL performance in men is that cognitive function might have contributed more to IADL performance in men than in women. IADL were reported to be associated with memory and executive functioning in patients with mild Alzheimer's disease.[17] The absence of a relationship between KE strength and IADL performance in men could be partly explained if one argued that cognitive function played a greater role in men, especially because the men were older than the women. As aforementioned, however, the MMSE was related to IADL in women only. The average MMSE score was not different between men and women. Thus, it seems unlikely that cognitive function played a greater role in men than in women in determining IADL performance.

Another possible explanation is that effects of diseases were overshadowing the effect of KE strength. IADL was associated with a history of stroke, heart disease and asthma in men, but only with stroke in women. It is conceivable that IADL in men was more affected by medical conditions than women. Conceptual tradition in Japan regarding family roles might result in the maintenance of IADL irrespective of diseases. According to an international social survey, 77.7% of Japanese married people stated that grocery shopping was usually done by the woman within a couple, compared with 34–57% in six other developed countries.[18] The same trend follows for doing laundry and preparing meals.[18] Our data also show that 37.2% of the women were living alone compared with 8.1% of the men. High dependency on the woman for household jobs and the high percentage of women living alone suggest that women were carrying out many daily physical activities, which might have prevented the deterioration of IADL in response to disease.

Relative dominance by women of household jobs could also suggest a limitation of using TMIG-IADL to evaluate the IADL, especially in Japanese men. At least two questions in TMIG-IADL (Table 2) are closely related to jobs mainly carried out by women in Japan. We might need an improved index of IADL that is more sensitive in healthier men.

The present study showed that in women, KE strength correlated positively with IADL score, and the

degree of IADL disability decreased with increasing KE strength. This correlation was not observed in men. We might need to study a frail population to identify a correlation in men. We conclude that elderly women need to take measures to prevent lower-limb muscles from declining to maintain IADL.

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Disclosure statement

No potential conflicts of interest were disclosed.

References

1 Lawton MP, Brody EM. Assessment of older people: self-maintaining and instrumental activities of daily living. *Gerontologist* 1969; **9**: 179–186.
2 Judge JO, Schechtman K, Cress E. The relationship between physical performance measures and independence in instrumental activities of daily living. The FICSIT Group. Frailty and Injury: Cooperative Studies of Intervention Trials. *J Am Geriatr Soc* 1996; **44**: 1332–1341.
3 Sallinen J, Stenholm S, Rantanen T, Heliovaara M, Sainio P, Koskinen S. Hand-grip strength cut points to screen older persons at risk for mobility limitation. *J Am Geriatr Soc* 2010; **58**: 1721–1726.
4 Ishizaki T, Watanabe S, Suzuki T, Shibata H, Haga H. Predictors for functional decline among nondisabled older Japanese living in a community during a 3-year follow-up. *J Am Geriatr Soc* 2000; **48**: 1424–1429.
5 Uchida H, Mino Y, Tsuda T *et al.* Relation between the instrumental activities of daily living and physical fitness tests in elderly women. *Acta Med Okayama* 1996; **50**: 325–333.
6 Azegami M, Ohira M, Miyoshi K *et al.* Effect of single and multi-joint lower extremity muscle strength on the functional capacity and ADL/IADL status in Japanese community-dwelling older adults. *Nurs Health Sci* 2007; **9**: 168–176.
7 Sipila S, Suominen H. Knee extension strength and walking speed in relation to quadriceps muscle composition and training in elderly women. *Clin Physiol* 1994; **14**: 433–442.
8 Manini TM, Visser M, Won-Park S *et al.* Knee extension strength cutpoints for maintaining mobility. *J Am Geriatr Soc* 2007; **55**: 451–457.
9 Pohl PS, Duncan P, Perera S *et al.* Rate of isometric knee extension strength development and walking speed after stroke. *J Rehabil Res Dev* 2002; **39**: 651–657.
10 Koyano W, Shibata H, Nakazato K, Haga H, Suyama Y. Measurement of competence: reliability and validity of the TMIG Index of Competence. *Arch Gerontol Geriatr* 1991; **13**: 103–116.
11 Tombaugh TN, McIntyre NJ. The mini-mental state examination: a comprehensive review. *J Am Geriatr Soc* 1992; **40**: 922–935.
12 Sheehan DV, Lecrubier Y, Sheehan KH *et al.* The Mini-International Neuropsychiatric Interview (M.I.N.I.): the development and validation of a structured diagnostic psychiatric interview for DSM-IV and ICD-10. *J Clin Psychiatry* 1998; **59** (Suppl 20): 22–33; quiz 34–57.
13 Tanimoto Y, Watanabe M, Sun W *et al.* Association between muscle mass and disability in performing instrumental activities of daily living (IADL) in community-dwelling elderly in Japan. *Arch Gerontol Geriatr* 2011; **54**: e230–e233.
14 Ishizaki T, Kai I, Kobayashi Y, Imanaka Y. Functional transitions and active life expectancy for older Japanese living in a community. *Arch Gerontol Geriatr* 2002; **35**: 107–120.
15 Rantanen T, Avlund K, Suominen H, Schroll M, Frandin K, Pertti E. Muscle strength as a predictor of onset of ADL dependence in people aged 75 years. *Aging Clin Exp Res* 2002; **14**: 10–15.
16 Hasegawa R, Islam MM, Lee SC, Koizumi D, Rogers ME, Takeshima N. Threshold of lower body muscular strength necessary to perform ADL independently in community-dwelling older adults. *Clin Rehabil* 2008; **22**: 902–910.
17 Hall JR, Vo HT, Johnson LA, Barber RC, O'Bryant SE. the link between cognitive measures and ADLs and IADL functioning in mild Alzheimer's: what has gender got to do with it? *Int J Alzheimers Dis* 2011; **2011**: 1–6.
18 International Social Survey Program (ISSP). International social survey program: family and changing gender roles II. Koeln: ICPSR version; 1994. [Cited 1 Jan 2013.] Available from URL: http://data.library.utoronto.ca/datapub/codebooks/icpsr/6914/cb6914.pdf

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ORIGINAL ARTICLE: EPIDEMIOLOGY, CLINICAL PRACTICE AND HEALTH

Development of an equation for estimating appendicular skeletal muscle mass in Japanese older adults using bioelectrical impedance analysis

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Aim: Bioelectrical impedance analysis has been reported to have high reliability and accuracy in assessing body composition. However, equations for estimating appendicular skeletal muscle mass are population-specific, and few have been developed for older Japanese adults. Thus, the purpose of the present study was to develop and validate an estimate equation for appendicular skeletal muscle mass using bioelectrical impedance analysis.

Methods: A total of 250 older adults aged 65 years and older participated in this study. Appendicular skeletal muscle mass was measured using dual-energy X-ray absorptiometry, and bioelectrical resistance was measured using a multifrequency bioelectrical impedance analyzer. Multiple regression analysis was applied to derive sex-specific estimation formulae using bioelectrical impedance analysis, and a Bland–Altman analysis was used to test agreement.

Results: The cross-validation results showed that the slopes and intercepts of the regression lines were approximately one and zero, respectively, and the coefficients of determination and standard errors of the estimate of the newly developed equations were similar between the two groups. Thus, the single sex-specific equations were developed using all participants as follows. Men: appendicular skeletal muscle mass = 0.197 × (impedance index) + 0.179 × (weight) − 0.019 (R^2 = 0.87, standard error of the estimate = 0.98 kg). Women: appendicular skeletal muscle mass = 0.221 × (impedance index) + 0.117 × (weight) + 0.881 (R^2 = 0.89, standard error of the estimate = 0.81 kg).

Conclusion: These new equations offer a valid option for assessing appendicular skeletal muscle mass in older Japanese adults. **Geriatr Gerontol Int 2014; 14: 851–857.**

Keywords: aging, bioelectrical impedance, body composition, sarcopenia, skeletal muscle mass.

Introduction

There are several changes in body composition (e.g. a decrease in bone and muscle mass, and an increase in the proportion of fat) that take place during the aging process.[1,2] Lower muscle mass is associated with lower strength, and could lead to the development of functional limitations and disability in old age.[3–6] Advanced skeletal muscle loss might also have the potential to impact quality of life, the need for supportive services and, ultimately, the need for long-term care in older adults.[5] Japan has one of the highest average life expectancies and average active life expectancies in the world. Consequently, it is possible that sarcopenia is more prevalent in Japan compared with other countries. Thus, it is important to assess the change in skeletal muscle mass, and establish a preventive strategy for sarcopenia.

Evidence shows that magnetic resonance imaging, computerized tomography (CT), and dual-energy X-ray absorptiometry (DXA) provide precise and reliable measurements of skeletal muscle, and can be considered as benchmark methods for measuring skeletal muscle.[7]

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However, cost, accessibility and radiation exposure limit the use of these measurement methods.[8] Conversely, bioelectrical impedance analysis (BIA) is a non-invasive, easily applicable, inexpensive and practical method that is used to assess body composition in population studies.[5] Several studies have also developed BIA equations for estimating whole-body skeletal muscle or fat-free mass (FFM).[8–18] However, most of these equations were derived from Western or young populations, and none have been developed using a representative older Japanese adult sample.

The BIA is convenient to assess body composition in epidemiological studies, but only if population-specific prediction formulas are used.[13] Generalized application to other populations is limited.[19] The BIA equation derived from Caucasians was shown to be applicable to Hispanic and African–Americans, but has not been validated for estimation of skeletal muscle in Asian populations.[10] Therefore, it has been suggested that BIA equations should be developed and validated for population-specific groups.[12] The purpose of the present study was to develop and validate a new BIA equation for estimating appendicular skeletal muscle (ASM) in older Japanese adults.

Methods

Participants

Previously, we carried out a population-based cohort study, the Obu Study of Health Promotion for the Elderly (OSHPE), from August 2011 to February 2012.[20] In the present study, participants were recruited from this existing database (n = 5104). Inclusion criteria required participants to be aged 65 years or older and living independently in Obu city, Aichi, Japan. Exclusion criteria were as follows: subjects who participated in other studies, a certified need for long-term care or impairment of activities of daily living, a severe visual or hearing impairment, a medical history (stroke, Parkinson's disease and other serious neurological diagnoses), clinical depression, wearing a pacemaker, or a Mini-Mental State Examination score <18. Finally, a total of 250 subjects aged 65 years and older participated in the present study. All participants were informed about the study procedures and provided written informed consent before participation. In addition, the present study was carried out in accordance with the Helsinki Declaration, and was approved by the ethics committee of the National Center for Geriatrics and Gerontology.

Anthropometric measurements

With the participants wearing light indoor clothes and no shoes, bodyweight was measured to the nearest 0.1 kg using calibrated digital electronic scales, and height was measured to the nearest 0.1 cm using a wall-mounted stadiometer. Body mass index (BMI) was calculated as weight (kg) divided by height (m) squared.

Measurement of bioelectrical impedance

A multifrequency bioelectrical impedance analyzer (MC-980A, Tanita, Tokyo, Japan) was used to measure bioimpedance. The BIA instrument used six electrical frequencies (1 kHz, 5 kHz, 50 kHz, 250 kHz, 500 kHz and 1000 kHz), and we calculated the impedance index, height^2 (cm) divided by resistance (Ω), after measurements were made. The participants stood barefoot on the analyzer platform, grasping the two handgrips. Eight-point tactile electrodes made contact with the palm and thumb of each hand, and with the anterior and posterior aspects of the sole of each foot. Surface electrodes were placed on the right side of the body, on the dorsal surface of the hands and feet proximal to the metacarpal- and metatarsal-phalangeal joints, respectively, and also medially between the distal prominences of the radius and ulna, and between the medial and lateral malleoli at the ankle. Measurements were carried out by well-trained staff, and completed within 30 s.

Previous studies evaluating the short- and long-term reliability of resistance measurements obtained from bioelectrical impedance have shown that the coefficients of variation (CV) were small, and ranged from 1.8% to 2.9%.[21] In the present study, the CV for repeated measurements within 5 days (n = 3) was similar to previous studies (CV = 1.9–3.0%).

Assessment of body composition

Whole-body DXA (QDR-4500A; Hologic, Waltham, MA, USA) was used to assess skeletal muscle mass. The system software calculated the total mass, soft tissue attenuation ratios and the bone mineral mass for the selected regions. The soft tissue attenuation ratio was used to divide regional bone mineral-free tissue into fat and fat-free components.

Measurements were carried out by a trained radiology technician with dual-energy X-ray beams at 100 and 140 KeV, and the scan followed the manufacturer's default methodology, with data analyzed using the 9.03D version of software. Participants were measured while wearing only a standard light cotton gown to minimize clothing absorption. The measurement was completed within 15 min.

Total body scanning area was divided into precise anatomical segments. The arms were separated from the trunk by a line passing through the humeral head and the apex of the axilla. The trunk was separated from the legs by a line passing from the iliac crest to the perineum. The head was excluded from the trunk by a horizontal line passing just below the mandible. The

Table 1 Characteristics of the participants

	All participants (n = 250)	Men (n = 141)	Women (n = 109)	P-value[a]
Age (years)	73.5 ± 5.6	73.7 ± 5.7	73.2 ± 5.5	0.47
Height (cm)	156.0 ± 9.0	161.8 ± 6.1	148.5 ± 6.1	<0.01
Weight (kg)	57.0 ± 10.6	61.2 ± 8.8	51.6 ± 10.3	<0.01
BMI (kg/m^2)	23.4 ± 3.4	23.4 ± 3.0	23.4 ± 3.9	0.97
ASM (kg)	17.8 ± 3.8	20.3 ± 2.7	14.6 ± 2.4	<0.01
Percent of body fat (%)	24.9 ± 6.8	21.0 ± 4.6	29.9 ± 5.7	<0.01
Osteoporosis (%)	10.8	5.0	18.3	<0.01
Fractures in old age (%)	13.6	7.1	22.0	<0.01

Values are mean ± standard deviation or %. [a]Significant difference between men and women. ASM, appendicular skeletal muscle mass; BMI, body mass index.

ASM was derived as the sum of fat-free soft tissues in the arms and legs, assuming that all non-fat and non-bone tissue was skeletal muscle.

Visser *et al.* validated the Hologic QDR-4500 instrument in older participants, and found that measured FFM was positively associated with FFM using a four-compartment model (R^2 = 0.98, standard error of the estimate [SEE] = 1.6 kg), and with CT at all four leg regions (R^2 = 0.86–0.96).[22] Two previous studies also reported that total body skeletal muscle mass could be accurately predicted from DXA-measured appendicular lean soft tissue mass.[23,24] To our knowledge, the CV using the QDR-4500 for measuring body composition has not been previously reported. However, the CV using the QDR-2000 (an old model Hologic) were 1.0% for FFM and 2.0% for fat mass.[25] Repeated daily measurements over 5 days in three participants showed that the CV of this measurement were 1.1% for FFM and 3.0% for fat mass.

Statistical analysis

We compared characteristics between men and women using paired t-tests or χ^2-tests where appropriate. Multiple regression analysis was used to develop sex-specific BIA equations. The ASM measured by DXA was used as the external criterion (dependent variable), and the impedance index that had the highest Pearson's correlation coefficient to the ASM was entered into the BIA model (independent variable). To develop a more precise fitting model, we examined other predictive variables using references to previous studies.[8–18] The anthropometric variable that had the highest Pearson's correlation coefficient to the ASM was also selected as the independent variable.

The BIA equation for estimating ASM was also developed using a double cross-validation technique. The total sample was randomly divided into two equal-sized groups (group A and B). A BIA equation was developed for each group, and then applied to the other group to validate each equation. The mean difference between the DXA-measured and the BIA-estimated ASM was tested using a paired t-test. If the cross-validation was satisfactory, groups were combined and a single equation was developed using all samples. Bland–Altman analysis was also used to test agreement.[26] All analyses were carried out using commercially available IBM SPSS statistics software (Version 19; SPSS, Chicago, IL, USA), and a significance level of $P < 0.05$ was accepted.

Results

Development of the new BIA equation for estimating ASM

Table 1 shows the demographic and anthropometric characteristics of the participants. There were significant sex-differences in height, weight, ASM, percent of fat, and prevalence of osteoporosis and fractures in old age (≥60 years). In the regression model, we selected independent variables based on the results of correlation analyses. Out of the six electrical frequencies, the impedance index at 50 kHz and above had a higher correlation (r = 0.94) to DXA-measured ASM compared with other electrical frequencies (r = 0.91 at 1 kHz and 5 kHz). With regard to the anthropometric variable, weight had the highest correlation with DXA-measured ASM (r = 0.88 for men, r = 0.89 for women; Table 2). As a result, the independent variables included impedance index at 50 kHz and weight. Sex-specific BIA equations used to estimate ASM in each group were as follows:

[Men]

Group A (n = 70): ASM = 0.200 × (impedance index) + 0.187 × (weight) − 0.878 (R^2 = 0.87, SEE = 1.01 kg)

Group B (n = 71): ASM = 0.191 × (impedance index) + 0.174 × (weight) + 0.816 (R^2 = 0.89, SEE = 0.91 kg)

Table 2 Correlation coefficients between appendicular skeletal muscle mass and other variables

		Ht^2/R	Height	Weight	BMI	Age
ASM	Men	0.83**	0.53**	0.88**	0.67**	−0.29**
	Women	0.89**	0.59**	0.89**	0.74**	−0.17

*$P < 0.05$; **$P < 0.01$. ASM, appendicular skeletal muscle mass; BMI, body mass index; Ht^2/R, impedance index (height^2/resistance) at 50 kHz.

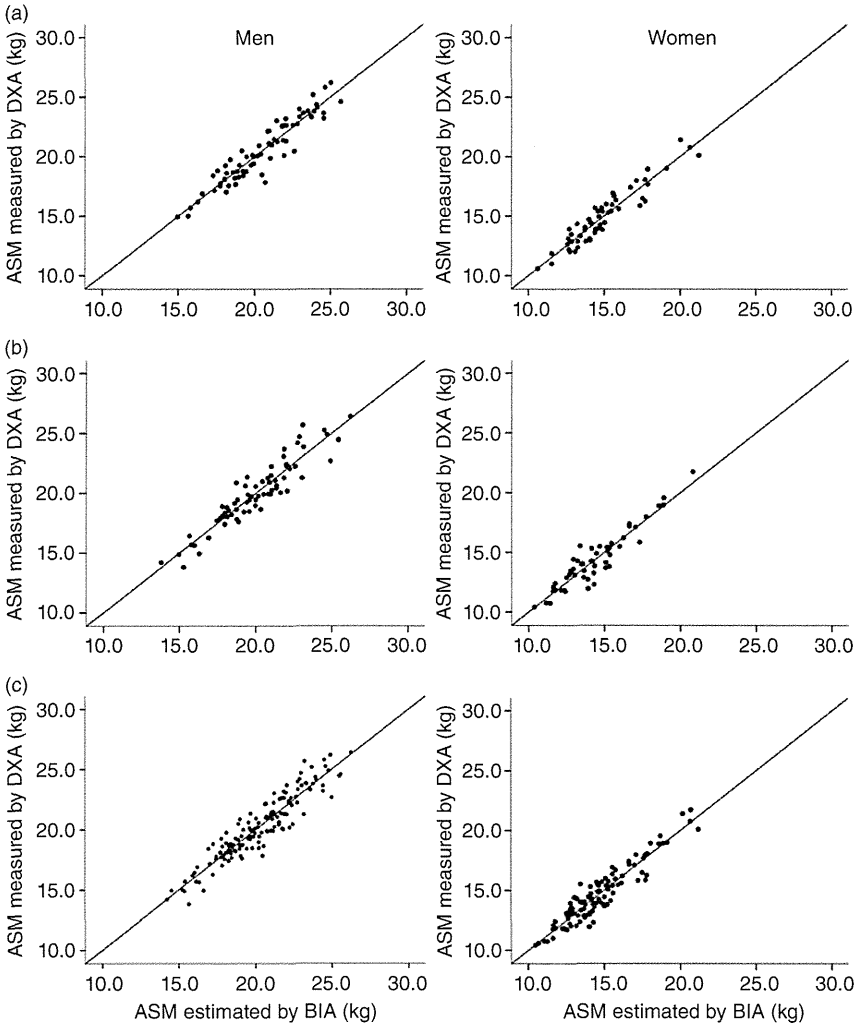

Figure 1 Estimation of appendicular skeletal muscle mass in (a) group A, (b) group B and (c) all participants. Solid line: regression line; dotted line: line of identity. ASM, appendicular skeletal muscle mass; BIA, bioelectrical impedance analysis; DXA: dual-energy X-ray absorptiometry.

[Women]

Group A ($n = 54$): ASM = 0.192 × (impedance index) + 0.133 × (weight) + 1.087 ($R^2 = 0.88$, SEE = 0.84 kg)

Group B ($n = 55$): ASM = 0.256 × (impedance index) + 0.099 × (weight) + 0.558 ($R^2 = 0.89$, SEE = 0.79 kg)

The BIA equations developed in group B were applied to the data of group A (Fig. 1a). Similarly, the BIA equations developed in group A were used to estimate ASM in group B (Fig. 1b). There were no significant differences between the BIA-estimated ASM and the DXA-measured ASM in both groups. The R^2 and SEE values were also similar between the two groups. Furthermore, regressions of BIA-estimated ASM on DXA-measured ASM for each group were almost identical with similar deviations from the line of identity. Thus, single equations using all participants were developed to

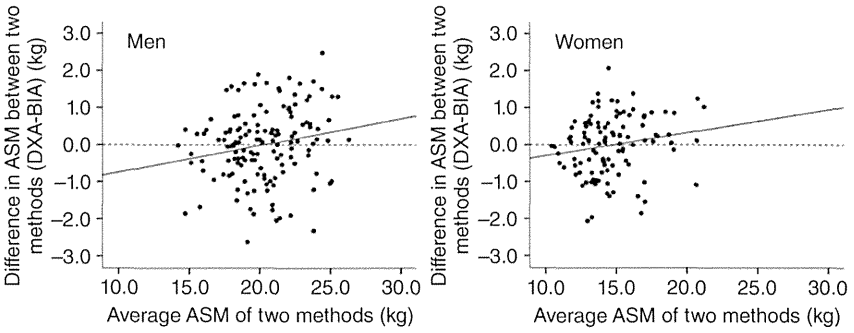

Figure 2 Bland–Altman plot for the difference in appendicular skeletal muscle mass (ASM) between dual-energy X-ray absorptiometry and bioelectrical impedance analysis, and the average ASM of the two methods. Solid line: regression line; dotted line: average difference in ASM between the two methods. BIA, bioelectrical impedance analysis; DXA: dual-energy X-ray absorptiometry.

estimate ASM (Fig. 1c). The BIA equations developed from all participants were as follows:
[Men]

$\text{ASM} = 0.197 \times (\text{impedance index}) + 0.179 \times (\text{weight}) - 0.019$. The model fit parameters (R^2 and SEE) were 0.87 and 0.98 kg, respectively.

[Women]

$\text{ASM} = 0.221 \times (\text{impedance index}) + 0.117 \times (\text{weight}) + 0.881$. The model fit parameters (R^2 and SEE) were 0.89 and 0.81 kg, respectively.

The mean differences between BIA-estimated and DXA-measured ASM were not significantly different. Systematic differences between the BIA-estimated and the DXA-measured ASM were determined using a Bland–Altman plot (Fig. 2). The BIA method tended to underestimate ASM in participants with high ASM, and overestimate ASM in participants with low ASM, but correlation coefficients between the difference in DXA-measured and BIA-estimated ASM and the average ASM of the two methods were small ($r = 0.19$ for men; $r = 0.17$ for women).

Discussion

Although several studies have developed BIA equations for estimating whole-body skeletal muscle or FFM,[8–18] most of these population-specific and generalized equations were derived from Western or young populations. It has been established that the validity of BIA equations depends on the population to which they are applied, as well as water distribution, fatness, ethnicity and body shape differences.[9] To assess body composition and diagnose sarcopenia more accurately, a BIA equation for estimation of ASM in older Japanese adults is required.

We selected variables for the regression model based on results obtained from correlation coefficients. Correlations were different in each of the six electric frequency bands, and the use of electric frequencies over 50 kHz did not improve performance of the BIA model. We therefore chose an impedance index at 50 kHz, which had the highest correlation ($r = 0.94$) to DXA-measured ASM. From the other potential variables, weight was included as an independent variable.

The new BIA equations explained 87% for men and 89% for women of the variance in DXA-measured ASM, and the model fit parameters were similar or superior to previous results estimating skeletal muscle or FFM by BIA ($R^2 = 0.70$–0.97). A greater contribution of impedance index to DXA-measured ASM was evident in the BIA model.

Bland–Altman analysis showed a tendency of systematic error with the BIA method. This tendency was observed in a previous study with Asian participants,[8] although the errors were small. The present results also showed that the differences between DXA-measured and BIA-estimated ASM ranged from +2.47 kg to −2.63 kg for men, and +2.07 kg to −2.06 kg for women, which are smaller compared with those in previous studies.[8,10] These results suggest that the new equations can provide valid, reliable and accurate estimates of ASM in older Japanese adults. These equations might allow efficient screening to identify sarcopenic patients from large samples, and clarify the prevalence of sarcopenia in older people.

There were some limitations of the current study. First, we could not strictly control the factors that could potentially affect the accuracy of BIA measurement. Despite participants with chronic diseases or prescribed medications being excluded, and most participants maintaining a relatively consistent pattern of lifestyle over the past year, it is likely that the time of measurement[27] and eating or exercise before measurement,[28,29] must be controlled to minimize potential error.[30] Second, we used DXA as the reference method, and estimated ASM using this measurement, and total ASM was taken as the sum of arm and leg values. This estimate included a small and relatively constant amount of skin and connective tissue, together with any intramuscular fat infiltration. Therefore, DXA-measured ASM might overestimate actual muscle mass. Furthermore, as a result of the cross-sectional designs of these findings, the long-term predictive validity of the equation has not yet been evaluated. Thus, subsequent studies

will be required to confirm the validity of the equation in longitudinally monitored populations.

In summary, we have developed new BIA equations for estimating ASM, and confirmed the validity of these equations. The cross-validation of the BIA equations was successful, and the magnitude of error in estimating ASM was small. These observations suggest that these new equations offer a valid option to assess ASM in older Japanese adults.

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Disclosure statement

No potential conflicts of interest were disclosed.

References

1 Baumgartner RN. Body composition in healthy aging. *Ann N Y Acad Sci* 2000; **904**: 437–448.
2 Gallagher D, Visser M, De Meersman RE *et al.* Appendicular skeletal muscle mass: effects of age, gender, and ethnicity. *J Appl Physiol* 1997; **83**: 229–239.
3 Baumgartner RN, Koehler KM, Gallagher D *et al.* Epidemiology of sarcopenia among the elderly in New Mexico. *Am J Epidemiol* 1998; **147**: 755–763.
4 Morley JE, Baumgartner RN, Roubenoff R, Mayer J, Nair KS. Sarcopenia. *J Lab Clin Med* 2001; **137**: 231–243.
5 Janssen I, Heymsfield SB, Ross R. Low relative skeletal muscle mass (sarcopenia) in older persons is associated with functional impairment and physical disability. *J Am Geriatr Soc* 2002; **50**: 889–896.
6 Janssen I. Influence of sarcopenia on the development of physical disability: the Cardiovascular Health Study. *J Am Geriatr Soc* 2006; **54**: 56–62.
7 Mitsiopoulos N, Baumgartner RN, Heymsfield SB, Lyons W, Gallagher D, Ross R. Cadaver validation of skeletal muscle measurement by magnetic resonance imaging and computerized tomography. *J Appl Physiol* 1998; **85**: 115–122.
8 Chien MY, Huang TY, Wu YT. Prevalence of sarcopenia estimated using a bioelectrical impedance analysis prediction equation in community-dwelling elderly people in Taiwan. *J Am Geriatr Soc* 2008; **56**: 1710–1715.
9 Roubenoff R, Baumgartner RN, Harris TB *et al.* Application of bioelectrical impedance analysis to elderly populations. *J Gerontol A Biol Sci Med Sci* 1997; **52**: M129–M136.
10 Janssen I, Heymsfield SB, Baumgartner RN, Ross R. Estimation of skeletal muscle mass by bioelectrical impedance analysis. *J Appl Physiol* 2000; **89**: 465–471.
11 Kyle UG, Genton L, Karsegard L, Slosman DO, Pichard C. Single prediction equation for bioelectrical impedance analysis in adults aged 20–94 years. *Nutrition* 2001; **17**: 248–253.
12 Dey DK, Bosaeus I, Lissner L, Steen B. Body composition estimated by bioelectrical impedance in the Swedish elderly. Development of population-based prediction equation and reference values of fat-free mass and body fat for 70- and 75-y olds. *Eur J Clin Nutr* 2003; **57**: 909–916.
13 Dey DK, Bosaeus I. Comparison of bioelectrical impedance prediction equations for fat-free mass in a population-based sample of 75 y olds: the NORA study. *Nutrition* 2003; **19**: 858–864.
14 Sun SS, Chumlea WC, Heymsfield SB *et al.* Development of bioelectrical impedance analysis prediction equations for body composition with the use of a multicomponent model for use in epidemiologic surveys. *Am J Clin Nutr* 2003; **77**: 331–340.
15 Rush EC, Puniani K, Valencia ME, Davies PS, Plank LD. Estimation of body fatness from body mass index and bioelectrical impedance: comparison of New Zealand European, Maori and Pacific Island children. *Eur J Clin Nutr* 2003; **57**: 1394–1401.
16 Rush EC, Chandu V, Plank LD. Prediction of fat-free mass by bioimpedance analysis in migrant Asian Indian men and women: a cross validation study. *Int J Obes (Lond)* 2006; **30**: 1125–1131.
17 Aleman-Mateo H, Rush E, Esparza-Romero J *et al.* Prediction of fat-free mass by bioelectrical impedance analysis in older adults from developing countries: a cross-validation study using the deuterium dilution method. *J Nutr Health Aging* 2010; **14**: 418–426.
18 Sluyter JD, Schaaf D, Scragg RK, Plank LD. Prediction of fatness by standing 8-electrode bioimpedance: a multiethnic adolescent population. *Obesity (Silver Spring)* 2010; **18**: 183–189.
19 Genton L, Karsegard VL, Kyle UG, Hans DB, Michel JP, Pichard C. Comparison of four bioelectrical impedance analysis formulas in healthy elderly subjects. *Gerontology* 2001; **47**: 315–323.
20 Shimada H, Makizako H, Doi T *et al.* Combined prevalence of frailty and mild cognitive impairment in a population of elderly Japanese people. *J Am Med Dir Assoc* 2013; **14**: 518–524.
21 Houtkooper LB, Lohman TG, Going SB, Howell WH. Why bioelectrical impedance analysis should be used for estimating adiposity. *Am J Clin Nutr* 1996; **64** (3 Suppl): 436S–448S.
22 Visser M, Fuerst T, Lang T, Salamone L, Harris TB. Validity of fan-beam dual-energy X-ray absorptiometry for measuring fat-free mass and leg muscle mass. *J Appl Physiol* 1999; **87**: 1513–1520.
23 Kim J, Wang Z, Heymsfield SB, Baumgartner RN, Gallagher D. Total-body skeletal muscle mass: estimation by a new dual-energy X-ray absorptiometry method. *Am J Clin Nutr* 2002; **76**: 378–383.
24 Chen Z, Wang Z, Lohman T *et al.* Dual-energy X-ray absorptiometry is a valid tool for assessing skeletal muscle mass in older women. *J Nutr* 2007; **137**: 2775–2780.
25 Slosman DO, Casez JP, Pichard C *et al.* Assessment of whole-body composition with dual-energy x-ray absorptiometry. *Radiology* 1992; **185**: 593–598.
26 Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986; **8**: 307–310.
27 Oshima Y, Shiga T. Within-day variability of whole-body and segmental bioelectrical impedance in a standing position. *Eur J Clin Nutr* 2006; **60**: 938–941.

28 Deurenberg P, Weststrate JA, Paymans I, van der Kooy K. Factors affecting bioelectrical impedance measurements in humans. *Eur J Clin Nutr* 1988; **42**: 1017–1022.
29 Gallagher MR, Walker KZ, O'Dea K. The influence of a breakfast meal on the assessment of body composition using bioelectrical impedance. *Eur J Clin Nutr* 1998; **52**: 94–97.
30 Kyle UG, Bosaeus I, De Lorenzo AD *et al.* Bioelectrical impedance analysis – part 1: review of principles and methods. *Clin Nutr* 2004; **23**: 1226–1243.

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ORIGINAL ARTICLE

Using two different algorithms to determine the prevalence of sarcopenia

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Aim: Several operative definitions and screening methods for sarcopenia have been proposed in previous studies; however, the opinions of researchers still differ. We compared the prevalence of sarcopenia using two different algorithms: (i) the European working group on sarcopenia in older people (EWGSOP)-suggested algorithm using gait speed as the first step; and (ii) the muscle mass and strength algorithm.

Methods: A population-based, cross-sectional survey of adults aged over 65 years was carried out. Data on a total of 4811 participants were available for analysis. Gait speed, grip strength and appendicular skeletal muscle mass were assessed to determine sarcopenia. Appendicular skeletal muscle mass was estimated from bioimpedance analysis measurements and expressed as skeletal muscle mass index. Grip strength and skeletal muscle mass index were considered to be low if they fell below the threshold of the lowest 20% of values measured in a subset of healthy subjects. We compared the prevalence rates of sarcopenia determined by the two algorithms.

Results: The prevalence rate of sarcopenia in a representative sample of older Japanese adults was 8.2% for men and 6.8% for women based on the EWGSOP algorithm. The two algorithms identified the same participants as sarcopenic, the only difference being the EWGSOP algorithm classified an additional seven participants (0.15%) into sarcopenia compared with the muscle mass and strength algorithm.

Conclusion: It is debatable whether inclusion of gait speed is necessary when screening for sarcopenia in community-dwelling older adults. Future research should examine the necessity of including gait speed in algorithms and the validity of cut-off values. **Geriatr Gerontol Int 2014; 14 (Suppl. 1): 46–51.**

Keywords: aging, prevalence, sarcopenia.

Introduction

Several changes in body composition occur with the aging process (e.g. a decrease in bone and muscle mass, and an increase in the proportion of fat).[1,2] Lower muscle mass is associated with decreased strength, and might lead to the development of functional limitations and disability in old age.[3–6] Advanced skeletal muscle loss could also potentially have an impact on quality of life, the need for supportive services and ultimately the need for long-term care in older persons.[5] Thus, it is important to develop a valid and feasible method to screen older adults for sarcopenia, and to establish a preventive strategy for sarcopenia in older people.

Although operative definitions and screening methods for sarcopenia have been proposed in previous studies, the opinions of researchers have been conflicting.[3,7–10] Recently, a European working group on sarcopenia in older people (EWGSOP) published their recommendations for a clinical definition, and consensus diagnostic criteria, for sarcopenia.[10] In that report, the EWGSOP suggested an algorithm using the presence of both low muscle mass and low muscle function, including strength and gait performance, for the diagnosis of sarcopenia. Low gait performance is the first step to identify sarcopenia in the EWSOP algorithm. Thus, it is possible that older adults with high gait

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performance would not be categorized as sarcopenic, even if they had evident muscle atrophy.

The term "sarcopenia" was coined by Rosenberg in 1989 to refer to the process of age-related loss of skeletal muscle mass.[11] Originally, "sarcopenia" derives from the Greek words *sarx* (meaning flesh) and *penia* (meaning loss), and this term is used to refer specifically to the gradual loss of skeletal muscle mass and strength that occurs with advancing age.[12] According to the original meaning, the definition and diagnosis of sarcopenia should be based on the reduction of muscle mass and strength. Furthermore, sarcopenia is a fundamental component of frailty, and it can be seen as one dimension of frailty. Frailty is a geriatric syndrome resulting from age-related cumulative declines across multiple physiological systems, and is characterized by the following five domains: unintended weight loss, self-reported exhaustion, weakness (reduced grip strength), slow gait speed and low levels of physical activity.[13] If sarcopenia patients are screened according to gait speed, sarcopenia becomes roughly synonymous with frailty, and it could confuse interpretation of both sarcopenia and frailty.

The purpose of the present study was to compare the difference in prevalence of sarcopenia determined using two different algorithms: (i) the EWGSOP algorithm, using gait speed as the first step; and (ii) the muscle mass and strength algorithm, and to examine whether gait speed should be a critical component for screening sarcopenia.

Methods

Participants

The present study was based on data collected as part of the Obu Study of Health Promotion for the Elderly (OSHPE), carried out in Obu, Aichi, Japan, from August 2011 to February 2012. OSHPE initially sent postal invitations to 14 313 persons aged 65 years and older, resident in the city of Obu. Individuals who had participated in previous studies, were hospitalized and/or in residential care, or were certified as requiring more than level 3 care needing support or care by the Japanese public long-term care insurance system were excluded from participation in OSHPE. A total of 5104 persons responded and agreed to participate in the present study (response rate: 35.7%). The overall survey consisted of face-to-face interviews on health status, physical and cognitive function tests, and body composition, among other items. Major chronic illnesses were assessed by nurses through face-to-face interviews. Chronic illnesses included in the study were hypertension, hyperlipidemia, diabetes mellitus, heart disease, stroke, Parkinson's disease, dementia, clinical depression, cancer, lung disease, osteoporosis and arthritis (rheumatoid and osteoarthritis).

Of the 5104 OSHPE participants, we excluded those with missing data on body composition, gait speed or muscle strength. Data on 4811 participants (94.3% of all participants, 2343 men and 2468 women) were available for this analysis. All participants were informed about the study procedures and provided written informed consent before participation. In addition, this study was carried out in accordance with the Helsinki Declaration, and was approved by the ethics committee of the National Center for Geriatrics and Gerontology.

Assessment of appendicular muscle mass

A multifrequency bioelectrical impedance analyzer (MC-980A; Tanita, Tokyo, Japan) was used to measure bioimpedance. This bioelectrical impedance analysis (BIA) instrument uses six electrical frequencies (1 kHz, 5 kHz, 50 kHz, 250 kHz, 500 kHz and 1000 kHz), and we calculated the impedance index, height^2 (cm) divided by resistance (Ω). The participants stood barefoot on the analyzer platform, grasping the two handgrips. Eight-point tactile electrodes made contact with the palm and thumb of each hand, and with the anterior and posterior aspects of the sole of each foot. Surface electrodes were placed on the right side of the body, on the dorsal surface of the hands and feet proximal to the metacarpal- and metatarsal-phalangeal joints, respectively, medially between the distal prominences of the radius and ulna, and between the medial and lateral malleoli at the ankle. Measurements were carried out by trained staff, and completed within 30 s.

We estimated appendicular skeletal muscle mass (ASM) using the following equations that were developed for Japanese older adults:[14]

$$\text{Men: ASM} = 0.197 \times (\text{impedance index}) + 0.179 \times (\text{weight}) - 0.019$$

$$\text{Women: ASM} = 0.221 \times (\text{impedance index}) + 0.117 \times (\text{weight}) + 0.881$$

Skeletal muscle mass index (SMI) was calculated as ASM / height.^{2}

Measurement of muscle strength

Maximal voluntary isometric strength of handgrip was measured using a hand dynamometer Grip-D (Takei, Niigata, Japan). The measurement was taken with the dominant hand in a standing position. The muscle strength test was carried out once only. Handgrip strength has been widely used to measure muscle strength and correlates well with most relevant outcomes.[15]

Measurement of gait speed

Participants were asked to walk 6.4 m (divided into two 2.0-m zones at each end, and a 2.4-m middle-zone) at their usual pace. We measured the required time (in seconds) to pass the 2.4-m middle zone to calculate gait speed (m/s). Use of a cane or walker was permitted if participants could not practice the gait test. The gait test was carried out five times, and the average value was used.

Gait speed is a valid and widely used measure of mobility limitation for both healthy and impaired older persons,[16] with high predictive validity for subsequent disability, hospitalization and mortality.[17,18]

Algorithm and cut-off values to determine sarcopenia

We used the EWGSOP-algorithm as one method to determine the individuals with sarcopenia. We also used the muscle mass and strength algorithm. The EWGSOP recommends use of normative (healthy young adult) rather than other predictive reference populations, with cut-off points (for muscle mass and strength) at two standard deviations below the mean reference value.[10] However, no reference data from a normative Japanese population were available with which to determine cut-off values for grip strength and SMI. In the absence of normative reference populations, previous studies have used healthy older adults as their reference groups (applying cut-off points derived from the lowest sex-specific quartiles[13] or quintiles[9,19]). To overcome this limitation, we selected a healthy subset of people from our study, and used their sex-specific quintile points (lowest 20%) as cut-off values. This healthy subset was defined as follows: no impairment of activities of daily living, no medical history (stroke, Parkinson's disease, Alzheimer's disease or other serious neurological diagnoses, depression), gait speed ≥1.0 m/s and Mini-Mental State Examination (MMSE) score ≥21. Participants were classified as "low level" when their grip strength or SMI values fell below the cut-off points. In the EWGSOP-algorithm, a gait speed at 0.8 m/s is used as the cut-off value.[10]

Statistical analysis

Differences in age, body mass index (BMI), SMI, gait speed, grip strength, and MMSE score were compared between those with and without sarcopenia using *t*-tests by sex. The prevalence of major chronic illnesses was also compared between those with and without sarcopenia using χ^2-tests. All analysis was carried out using commercially available software, IBM SPSS statistics (version 19; SPSS, Chicago, IL, USA), and the level of significance was as set at $P < 0.05$.

Results

Determination of the cut-off values for sarcopenia

A total of 3810 (74.6% of all participants, 1848 men and 1962 women, mean age 71.2 ± 4.9 years) were included in the healthy subset of people used to determine cut-off values. Cut-off values of grip strength were set at 28.8 kg and 18.2 kg for men and women, respectively. Similarly, cut-off values of SMI were set at 7.09 kg/m^2 in men and 5.91 kg/m^2 in women.

Prevalence and characteristics of sarcopenia

Data on a total of 4811 participants (94.3% of all participants, 2343 men and 2468 women) were available for analysis. The mean age was 72.2 ± 5.5 years in men and 72.1 ± 5.7 in women. The mean SMI was 7.71 ± 0.79 kg/m^2 in men and 6.51 ± 0.70 kg/m^2 in women.

According to the EWGSOP-algorithm, 7.5% (n = 360) of all participants were classified as having sarcopenia. The prevalence of sarcopenia was 8.2% for men and 6.8% for women, but this difference was not significant ($P = 0.09$). The prevalence of sarcopenia increased with age in both men and women, with people aged 80 years and older having the highest prevalence rates (25.0% in men and 12.2% in women, Fig. 1).

The characteristics of normal and sarcopenic participants are summarized in Table 1. Compared with the normal participants, both male and female sarcopenic participants were significantly older ($P < 0.01$) and had lower BMI ($P < 0.01$). In addition, there were significant differences in the proportions of participants with hypertension ($P < 0.01$) and osteoporosis ($P < 0.01$).

We also calculated the prevalence of sarcopenia using the muscle mass and strength algorithm, and compared the prevalence of sarcopenia determined using the two methods (Fig. 2). The present results showed that the two algorithms produced similar overall estimates of sarcopenia prevalence (7.5% *vs* 7.3% using the

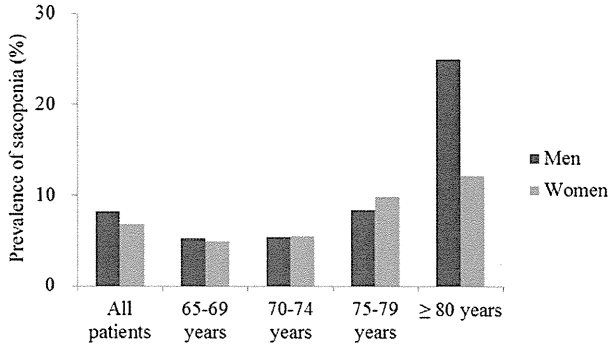

Figure 1 The prevalence of sarcopenia by age category and sex.

Table 1 Comparison of characteristics of those with and without sarcopenia by sex according to the European working group on sarcopenia in older people algorithm

Variables		Men			Women		
		Normal (n = 2,152)	Sarcopenia (n = 191)	P-value	Normal (n = 2,299)	Sarcopenia (n = 169)	P-value
Age	years	71.8 ± 5.2	76.0 ± 7.2	<0.01	71.9 ± 5.5	74.5 ± 7.0	<0.01
BMI	kg/m^2	24.0 ± 2.7	19.9 ± 1.6	<0.01	23.5 ± 3.2	19.0 ± 1.8	<0.01
SMI	kg/m^2	7.8 ± 0.7	6.6 ± 0.4	<0.01	6.6 ± 0.7	5.5 ± 0.3	<0.01
Diagnosis	%						
Hypertension		49.1	34.6	<0.01	45.1	34.3	<0.01
Diabetes mellitus		15.8	17.8	0.46	11.0	4.7	0.01
Stroke		7.1	8.4	0.50	3.8	4.1	0.82
Heart disease		19.2	16.2	0.32	13.9	14.8	0.75
Respiratory disease		12.8	20.9	<0.01	9.1	12.4	0.16
Cancer		11.4	16.2	0.05	8.5	5.3	0.15
Osteoporosis		1.1	6.3	<0.01	19.2	31.4	<0.01
Gait speed	m/s	1.3 ± 0.2	1.1 ± 0.2	<0.01	1.3 ± 0.2	1.2 ± 0.3	<0.01
Grip strength	kg	33.7 ± 5.8	24.5 ± 3.2	<0.01	21.3 ± 4.0	15.8 ± 2.5	<0.01
MMSE	score	25.9 ± 2.7	24.8 ± 3.2	<0.01	26.5 ± 2.8	26.1 ± 3.4	0.13

Values are mean ± SD or %. ASM, appendicular skeletal muscle mass; BMI, body mass index; MMSE, Mini-Mental State Examination; SMI, skeletal muscle index.

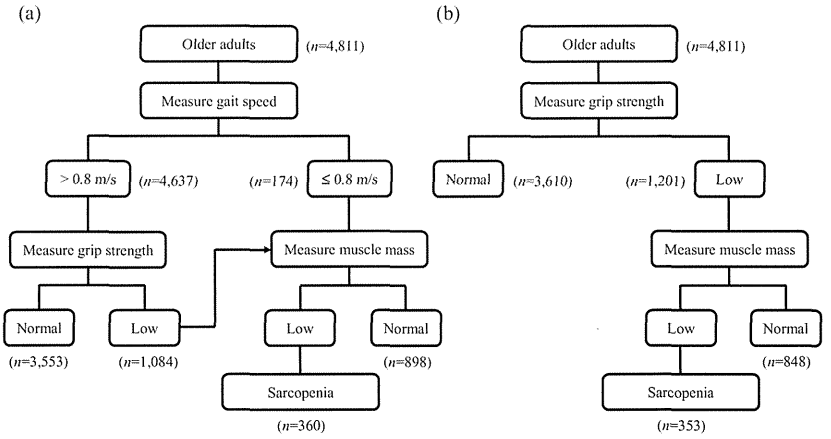

Figure 2 The prevalence of sarcopenia in the community setting determined using two different algorithms. (a) The European working group on sarcopenia in older people-suggested algorithm of sarcopenia. (b) The algorithm based on muscle strength and muscle mass to determine sarcopenia.

EWGSOP and muscle mass and strength algorithms, respectively). The same participants were identified by both algorithms, with the exception of seven people (0.15%) who were classified as having sarcopenia using the EWGSOP-algorithm, but who did not have sarcopenia according to the muscle mass and strength algorithm. Conversely, all of the participants (n = 353) classified with sarcopenia by the muscle mass and strength algorithm were also defined as having sarcopenia using the EWGSOP-algorithm.

Discussion

The EWGSOP recommends that cut-off values for handgrip strength were 30.0 kg in men and 20.0 kg in women.[10] In a sample of Japanese older adults, Tanimoto *et al.* reported the cut-off values for low grip strength were 30.3 kg in men and 19.3 kg in women.[20] However, the EWGSOP recommendations were based on results that included non-Japanese participants. Tanimoto *et al.* recruited regular attendees of welfare centers for the aged or community centers to their study.[20] As a result, the generalizability of their results might be limited, and it may not be appropriate to apply their cut-off values in the present study. The present study, using a similar methodology as several previous studies, applied the lowest quintile of grip strength in a healthy subset of subjects (aged ≥65 years) as the cut-off point. The cut-off values for grip strength determined using this method were slightly lower than those published in previous studies. The validity of the cut-off points used in the present study remains to be determined.

We also used sex-specific quintile points (lowest 20%) as the cut-off values for SMI, and these values were similar to previously reported cut-off points of >2 standard deviations less than the mean value for young Japanese adults (7.0 kg/m^2 in men and 5.8 kg/m^2 in women).[20] These results suggest that the lowest 20% of SMI in Japanese older adults could be a useful substitute for the value two standard deviations below the sex-specific mean SMI of young adults.

Using the EWGSOP-algorithm, 7.5% of all participants were classified as having sarcopenia. The prevalence of sarcopenia in older adults has been widely investigated in European and American countries, and most of these values ranged from 10% to 30%.[3,5,21,22] Reports published on the prevalence of sarcopenia in older adults in Asian countries have tended to show a lower prevalence of sarcopenia in Japan (11.3% and 10.7% in men and women, respectively),[20] Korea (12.1% and 11.9% in men and women, respectively),[23] Hong Kong (12.3% and 7.6% in Chinese men and women, respectively)[24] and Taiwan (23.6% and 18.6% in men and women, respectively).[25] The present study found a similarly low prevalence of sarcopenia. Differences in the prevalence rate of sarcopenia between studies might be as a result of real differences between races and regions. However, because of differences in the operative definitions and screening methods used to detect sarcopenia, we could not directly compare our results with other studies. In addition, the cut-off values for grip strength that we used were slightly lower than those of previous studies. This might lead to an underestimation of the prevalence rate of sarcopenia in our sample. Additional studies are required not only to confirm the validity of cut-off points, but also to determine the standardized definition of sarcopenia.

We tested two screening methods for determining sarcopenia in the present study: (i) the EWGSOP-suggested algorithm using gait speed as the first step; and (ii) the muscle mass and strength algorithm. The resulting prevalence rates of sarcopenia corresponded closely. Although the EWGSOP-algorithm uses a measurement of gait speed as the first step with a cut-off point of 0.8 m/s, there were few people whose gait speed was below 0.8 m/s in our sample of community-dwelling older adults. In addition, most participants categorized as slow (gait speed <0.8 m/s) also had muscle weakness. In fact, Buchner *et al.* reported that the relationship between muscle strength and gait speed was non-linear, and small changes in muscle strength could have substantial effects on gait speed in frail adults, whereas large changes in muscle strength have little or no effect in healthy adults.[26] The EWGSOP report does not specifically recommend a method for measuring gait speed, and variations in methodology exist (e.g. walking courses may or may not include acceleration and deceleration phases). Differences in the methodology used to measure gait speed could be one reason why a cut-off point of 0.8 m/s was too low for the present study. In any case, we consider that a cut-off value of 0.8 m/s will be too slow if the acceleration and deceleration phases are excluded from the measurement of gait speed. It is debatable whether gait speed is necessary for screening sarcopenic participants in community-dwelling older adults. Future research should examine the necessity of including gait speed in algorithms and the validity of cut-off values.

The present study had several limitations that should be recognized. First, the response rate to postal invitation was 35.7%, and as a result, it is possible that our study suffered from selection bias. Second, we estimated the appendicular skeletal muscle mass by BIA methods. Although BIA is reported to be a highly reliable and accurate method of assessing muscle mass, the accuracy of BIA measurement can be affected by factors such as hydration status, food intake and exercise.[27] Older adults in particular can often have disturbances in water balance and/or extracellular water retention (e.g. edema). Yamada *et al.* suggested that extracellular water might mask actual muscle atrophy.[28] More precise methods (dual-energy X-ray absorptiometry or magnetic resonance image) should be used in future to assess muscle mass. Third, we used pragmatic cut-off points for determining sarcopenia. It is currently unclear whether the sex-specific lowest 20% was the best value for screening sarcopenic participants. Additional longitudinal studies will be required to confirm the predictive validity of the cut-off values in the future.

The present study showed that the prevalence of sarcopenia in a representative sample of older Japanese adults was 8.2% for men and 6.8% for women based on the EWGSOP-algorithm. When compared with the muscle mass and strength algorithm, the EWSOP-algorithm classified seven additional people (0.15%) into sarcopenia. Future research should examine the necessity of including gait speed in algorithms and the validity of cut-off values.

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Disclosure statement

The authors declare no conflict of interest.

References

1 Baumgartner RN. Body composition in healthy aging. *Ann N Y Acad Sci* 2000; **904**: 437–448.
2 Gallagher D, Visser M, De Meersman RE *et al.* Appendicular skeletal muscle mass: effects of age, gender, and ethnicity. *J Appl Physiol* 1997; **83**: 229–239.
3 Baumgartner RN, Koehler KM, Gallagher D *et al.* Epidemiology of sarcopenia among the elderly in New Mexico. *Am J Epidemiol* 1998; **147**: 755–763.
4 Morley JE, Baumgartner RN, Roubenoff R, Mayer J, Nair KS. Sarcopenia. *J Lab Clin Med* 2001; **137**: 231–243.
5 Janssen I, Heymsfield SB, Ross R. Low relative skeletal muscle mass (sarcopenia) in older persons is associated with functional impairment and physical disability. *J Am Geriatr Soc* 2002; **50**: 889–896.
6 Janssen I. Influence of sarcopenia on the development of physical disability: the Cardiovascular Health Study. *J Am Geriatr Soc* 2006; **54**: 56–62.
7 Evans WJ. What is sarcopenia? *J Gerontol A Biol Sci Med Sci* 1995; **50**: Spec No: 5–8.
8 Lauretani F, Russo CR, Bandinelli S *et al.* Age-associated changes in skeletal muscles and their effect on mobility: an operational diagnosis of sarcopenia. *J Appl Physiol* 2003; **95**: 1851–1860.
9 Newman AB, Kupelian V, Visser M *et al.* Sarcopenia: alternative definitions and associations with lower extremity function. *J Am Geriatr Soc* 2003; **51**: 1602–1609.
10 Cruz-Jentoft AJ, Baeyens JP, Bauer JM *et al.* Sarcopenia: European consensus on definition and diagnosis: report of the European Working Group on Sarcopenia in Older People. *Age Ageing* 2010; **39**: 412–423.
11 Rosenberg IR. Summary comments. *Am J Clin Nutr* 1989; **50**: 1231–1233.
12 Rosenberg IH. Sarcopenia: origins and clinical relevance. *J Nutr* 1997; **127** (5 Suppl): 990S–991S.
13 Fried LP, Tangen CM, Walston J *et al.* Frailty in older adults: evidence for a phenotype. *J Gerontol A Biol Sci Med Sci* 2001; **56** (3): M146–M156.
14 Yoshida D, Shimada H, Park H *et al.* Development of an equation for estimating appendicular skeletal muscle mass in Japanese older adults using bioelectrical impedance analysis. *Geriatr Gerontol Int* (in press).
15 Roberts HC, Denison HJ, Martin HJ *et al.* A review of the measurement of grip strength in clinical and epidemiological studies: towards a standardised approach. *Age Ageing* 2011; **40**: 423–429.
16 Guralnik JM, Ferrucci L, Simonsick EM, Salive ME, Wallace RB. Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. *N Engl J Med* 1995; **332**: 556–561.
17 Guralnik JM, Ferrucci L, Pieper CF *et al.* Lower extremity function and subsequent disability: consistency across studies, predictive models, and value of gait speed alone compared with the short physical performance battery. *J Gerontol A Biol Sci Med Sci* 2000; **55** (4): M221–M231.
18 Cesari M, Kritchevsky SB, Penninx BW *et al.* Prognostic value of usual gait speed in well-functioning older people-results from the Health, Aging and Body Composition Study. *J Am Geriatr Soc* 2005; **53**: 1675–1680.
19 Delmonico MJ, Harris TB, Lee JS *et al.* Alternative definitions of sarcopenia, lower extremity performance, and functional impairment with aging in older men and women. *J Am Geriatr Soc* 2007; **55**: 769–774.
20 Tanimoto Y, Watanabe M, Sun W *et al.* Association between sarcopenia and higher-level functional capacity in daily living in community-dwelling elderly subjects in Japan. *Arch Gerontol Geriatr* 2012; **55** (2): e9–13.
21 Iannuzzi-Sucich M, Prestwood KM, Kenny AM. Prevalence of sarcopenia and predictors of skeletal muscle mass in healthy, older men and women. *J Gerontol A Biol Sci Med Sci* 2002; **57** (12): M772–M777.
22 Masanes F, Culla A, Navarro-Gonzalez M *et al.* Prevalence of sarcopenia in healthy community-dwelling elderly in an urban area of Barcelona (Spain). *J Nutr Health Aging* 2012; **16**: 184–187.
23 Ryu M, Jo J, Lee Y, Chung YS, Kim KM, Baek WC. Association of physical activity with sarcopenia and sarcopenic obesity in community-dwelling older adults: the Fourth Korea National Health and Nutrition Examination Survey. *Age Ageing* 2013; **42**: 734–740.
24 Lau EM, Lynn HS, Woo JW, Kwok TC, Melton LJ 3rd. Prevalence of and risk factors for sarcopenia in elderly Chinese men and women. *J Gerontol A Biol Sci Med Sci* 2005; **60**: 213–216.
25 Chien MY, Huang TY, Wu YT. Prevalence of sarcopenia estimated using a bioelectrical impedance analysis prediction equation in community-dwelling elderly people in Taiwan. *J Am Geriatr Soc* 2008; **56**: 1710–1715.
26 Buchner DM, Larson EB, Wagner EH, Koepsell TD, de Lateur BJ. Evidence for a non-linear relationship between leg strength and gait speed. *Age Ageing* 1996; **25**: 386–391.
27 Janssen I, Heymsfield SB, Baumgartner RN, Ross R. Estimation of skeletal muscle mass by bioelectrical impedance analysis. *J Appl Physiol* 2000; **89**: 465–471.
28 Yamada Y, Schoeller DA, Nakamura E, Morimoto T, Kimura M, Oda S. Extracellular water may mask actual muscle atrophy during aging. *J Gerontol A Biol Sci Med Sci* 2010; **65**: 510–516.

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Original Article

Self-reported Exhaustion is Associated with Small Life Space in Older Adults with Mild Cognitive Impairment

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Abstract. [Purpose] Older adults experience exhaustion-induced health problems, such as poor physical function and low physical activity levels. The associations between self-reported exhaustion and physical function and activity are not clear in older adults with mild cognitive impairment (MCI). The aim of this study was to investigate the relationships between self-reported exhaustion and physical function and activity in older adults with mild cognitive impairment. [Subjects] A total of 356 older adults with mild cognitive impairment (mean age = 71.6 ± 0.3 years, 50.8% women) were included in this study. [Methods] Self-reported exhaustion was identified by one item from the Study of Osteoporotic Fractures index. Gait speed, gait endurance, and life space were also assessed. [Results] Sixty-two participants reported having exhaustion, giving a 17.4% prevalence of self-reported exhaustion among these individuals. Logistic regression analysis showed that the Life-Space Assessment score was the only parameter significantly independently associated with exhaustion status (adjusted odds ratio 0.97, 95% confidence interval 0.95–0.99). [Conclusion] These results suggest that self-reported exhaustion is associated with life space. Future research is needed to identify ways for older people with MCI to improve their exhaustion status.
Key words: Mild cognitive impairment, Self-reported exhaustion, Life space

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INTRODUCTION

Mild cognitive impairment (MCI) is considered to be the transitional phase between normal aging and dementia and is recognized as the prodromal stage of Alzheimer's disease (AD), which is the most common form of dementia[1)]. Evidence from neuropsychological and neuroimaging studies have suggested that mild cognitive impairment (MCI) represents a clinical prodromal status for degenerative dementias such as AD[2)]. For example, a population-based study in Sweden reported that the relative risks of progression to dementia in a 3 year follow-up in subjects with mild, moderate, and severe cognitive impairment without dementia were 3.6, 5.4, and 7.0, respectively[3)]. Older people with MCI show not only cognitive decline but also frailty, which is one of the most crucial health issues among older adults[4)].

The concept of frailty comprises five general factors: shrinking, weakness, exhaustion, slowness, and a low activity level[5, 6)]. Older adults with cognitive impairment, including MCI, are at higher risk of becoming frail than older adults who are cognitive healthy. In addition, older non-frail individuals with lower cognitive scores are significantly more likely to acquire one or more components of frailty over 10 years compared with those with higher cognitive scores[7)]. In turn, older adults with cognitive decline, such as MCI, are more vulnerable, so it is not enough to approach them from the standpoint of cognitive function only.

Among the five factors of the frailty concept, exhaustion in particular contributes to a more rapid onset of frailty and affects 80% of frail older adults[8)]. Based on self-reported symptoms, exhaustion was defined as a condition characterized by unusual fatigue or a general loss of energy. Exhaustion in the older population results from lower physiological capacity, as reflected in less total energy expenditure and a low physiological reserve compared with younger people[9)]. These effects lead to an inactive lifestyle that is accompanied by behavioral changes to save energy, thus preventing exhaustion from daily activities[9)], and a subsequent decline in physical or cognitive function. In fact, self-reported exhaustion negatively affects functions among older people: gait speed[10)], gait endurance[11)], physical activity[12)], and

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cognitive function[13]. So, self-reported exhaustion in older people is one of the health problems to prevent.

In older adults with MCI, maintaining physical performance through a physically active lifestyle may play an important role in delaying or preventing dementia[14]. It remains unclear whether or not older people with MCI have the association with self-reported exhaustion, although self-reported exhaustion was found to be negatively associated with physical function and physical activity among healthy older adults. Thus, it is important to clarify the relationship between exhaustion and physical function, including physical activity, in older adults with MCI. The first aim of this study was to investigate the prevalence of exhaustion among older adults with MCI and to compare it with the prevalence of exhaustion in the elderly population, which is estimated to be about 20%[15]. The second aim of this study was to investigate the prevalence of self-reported exhaustion among older adults with MCI and whether exhaustion is related to physical ability and physical activity levels.

SUBJECTS AND METHODS

The study population and data in this study were obtained at baseline in a larger cohort study, the Obu Study of Health Promotion for the Elderly (OSHPE)[16]. The classification of an individual as having MCI was based on the consensus previously published by Petersen[1]. These criteria included (1) a subjective memory complaint, (2) objective cognitive decline, (3) intact general cognitive function (mini-mental state examination (MMSE) score > 23)[17], (4) ability to perform activities of daily living (ADL) independently, and (5) absence of clinical criteria indicating dementia. Objective cognitive decline was defined as being indicated by a score of more than 1.5 standard deviations from the score for healthy in the OSHPE database after adjustment for age[16]. We assessed objective cognitive function using the National Center for Geriatrics and Gerontology Functional Assessment Tool. This software is used on a tablet PC and contains a battery of cognitive tests; the details of these tests have been described in detail elsewhere[18]. The tests comprise eight tasks to assess memory, attention, executive memory, processing speed, and visuospatial skills. Six hundred forty-nine older adults with MCI were selected from the larger cohort study as the potential study population for this study. After applying the exclusion criteria, 356 people with MCI were deemed suitable to participate in the current study. The exclusion criteria were: (1) history of cerebrovascular disease, Parkinson's disease, depression, or connective tissue disease; (2) presence of a heart pacemaker; (3) severe auditory or visual deficit; (4) depression symptoms (Geriatric Depression Scale-15 score > 5)[19]; or (5) prior commitment to other studies. Informed consent was obtained from all participants before inclusion in the study, and the Ethics Committee of the National Center for Gerontology and Geriatrics approved the study protocol.

Demographic data were collected including age, sex, number of medications, and body mass index (BMI). Self-reported exhaustion was identified using a questionnaire "Do you feel full of energy?" from the Study of Osteoporotic Fractures (SOF) index[5]. Participants who responded "No" to the question were placed in the exhausted group (EG), and those who answered "Yes" were placed in the nonexhausted group (non-EG). The SOF index has been found to be as reliable and valid as the Cardiovascular Health Study (CHS) index which is used most in the world, and this is reliability. In fact, Ensrud et al. showed that in the SOF index predicted disability, fracture, and death as well as the more complex CHS index even though the SOF index is a simple index[5, 20].

To measure gait speed, participants were asked to walk on a straight walkway (flat floor, 11 m long) at a comfortable and consistent gait speed. Gait speed was measured over a 5 m distance from the midpoint of the walkway. The capacity for gait endurance was assessed using the 6 min walk test (6MWT), which was performed as described previously[21]. Participants were instructed to walk as far as possible in 6 min along a 10 m course. The distance (in meters) walked during the 6 min was recorded as the gait endurance. Licensed and well-trained physical therapists assessed these physical performance tests.

The life space of older adults was assessed using a Japanese translation of Life-Space Assessment (LSA)[22, 23]. Scores on the LSA range from 0 to 120, with higher scores reflecting a larger life space. The frequency of movement (how many days per week) for the five different life space levels was reported by the participants for four weeks before the assessment. These levels are (1) rooms of the home besides where one sleeps; (2) an area directly outside the home (e.g., porch); (3) places in one's neighborhood, other than one's yard or apartment building; (4) places outside one's neighborhood but within one's town; and (5) places outside one's town. Participants were also asked whether they had assistance from another person or devices to reach each level of life space. The overall life space score was computed by summing the products of the each life space level (1–5) multiplied by: (a) degree of independence (2 = independent, 1.5 = used equipment, 1 = had personal assistance) and by (b) frequency of attainment (1 = less than once per week, 2 = 1–3 times per week, 3 = 4–6 times per week, 4 = daily).

Differences between groups were examined using the Wilcoxon signed-rank test for nonparametric data or Student's t test for parametric data. Only sex (dichotomous outcome) was analyzed using a χ^2 test. Then, multivariate logistic regression analysis was used to investigate whether the potential determinants were associated independently with self-reported exhaustion, and odds ratios (OR) and 95% confidence intervals (95% CI) were calculated. In the adjusted model, we examined the association of each variable (gait speed, gait endurance, and life space) with self-reported exhaustion status while accounting for all covariates (sex, age, BMI, number of medications, and MMSE score). In the fully adjusted model, we then identified which variables were independently related to self-reported exhaustion status when adjusted for gait speed, 6MWT result, LSA score, and all covariates. All analyses were performed using the IBM SPSS (Version 20; IBM Corp., Chicago, IL, USA). Significance was accepted at $p < 0.05$.

Table 1. Characteristics of participants in EG and non-EG

	All participants (n = 356)	non-EG (n = 294)	EG (n = 62)	p value
Sex (number of female) [n (%)]	181 (50.8)	145 (49.3)	36 (58.1)	0.26 [a]
Age (years) [mean ± SE]	71.6 ± 0.3	71.5 ± 0.3	71.9 ± 0.7	0.61
BMI (kg/m2) [mean ± SE]	23.4 ± 0.2	23.4 ± 0.2	23.4 ± 0.2	0.80
Medications (number of medication) [mean ± SE]	2.13 ± 0.11	2.05 ± 0.11	2.50 ± 0.29	0.11
MMSE (score) [mean ± SE]	26.7 ± 0.1	26.7 ± 0.1	27.1 ± 0.2	0.10
LSA (score)	90.4 ± 0.8	91.8 ± 0.9	83.9 ± 2.2	< 0.01
6MWT (m)	449.5 ± 4.1	453.2 ± 4.6	432.1 ± 9.1	< 0.05
Normal gait speed (m/sec)	1.36 ± 0.01	1.37 ± 0.01	1.33 ± 0.03	0.16

EG, Exhaustion group; SE, standard error; BMI, body mass index; MMSE, Mini-Mental State Examination; LSA, Life Space Assessment; 6MWT, 6 minutes walking test. a was χ^2 test and the other variables were student t test. Significance set at $p < 0.05$.

Table 2. Univariate and multiple logistic regression analyses showing the cross-sectional associations between exhaustion (dependent variable) and life-space assessment (independent variable) adjusted for the participants' characteristics

	Adjusted model [a]			Fully adjusted model [b]		
	OR	95% CI	p-value	OR	95% CI	p-value
LSA (score)	0.97	0.95–0.99	< 0.01	0.97	0.95–0.99	< 0.01
6MWT (m)	0.99	0.99–0.99	0.04	0.99	0.99–1.00	0.31
Normal gait speed (m/sec)	0.33	0.08–1.45	0.14	0.74	0.12–4.68	0.75

All analyses were adjusted for age, gender, BMI, number of medications, and Mini-Mental State Examination score. OR: odds ratio, CI: confidence interval, LSA: Life-Space Assessment, 6MWT: 6 min walking test. [a]: Each variable was included as an independent variable. [b]: All variables were including using a forced-entry method. Significance set at $p < 0.05$

RESULTS

The characteristics of the participants in the non-EG and EG are summarized in Table 1. Sixty-two participants were classified into the EG, giving a 17.4% prevalence of self-reported exhaustion. The participants' characteristics, including the MMSE score, did not differ significantly between the groups. The LSA scores and the 6MWT results (but not normal gait speed) were significantly lower ($p < 0.01$, $p < 0.05$, respectively) in the EG compared with the non-EG (Table 1).

The results of the logistic regression analyses are shown in Table 2. In the adjusted model, the LSA score (OR = 0.97, 95% CI; 0.95–0.99) and 6MWT results (OR = 0.99, 95% CI; 0.99–0.99) were independently associated with exhaustion status. However, in the fully adjusted model (model 3), only the LSA score was independently associated with exhaustion status (OR = 0.97, 95% CI; 0.95–0.99).

DISCUSSION

The results of this study showed that the prevalence of self-reported exhaustion was 17.4%. A previous study reported that the prevalence of self-reported exhaustion was 14.3% among older males and 20.4% among older females[15]. The prevalence among older adults with MCI in our study was similar to that of healthy older adults. People with MCI who self-reported exhaustion exhibited lower gait endurance performance and a lower LSA score compared with those without exhaustion. In the logistic analyses adjusted for covariates, the LSA score was significantly negatively associated with self-reported exhaustion, although there was no significant relationship between exhaustion and gait speed or gait endurance.

LSA comprises both the frequency and range of outdoor activities. With respect in the frequency of going outdoors, frequency going outdoors was positively associated with health status in older adults including psychological health, such as self-reported exhaustion, compared with older people who were housebound. Going outdoors frequently is positively associated with psychological health but not with physical function or ability to perform ADL[24, 25]. On the other hand, infrequently going outdoors is negatively associated with health problems among older people[26, 27]. Going outdoors less than once a week is linked to poorer psychological status, physical function, and ADL ability compared with going outdoors 2–3 times per week[24]. In the present study, the LSA score was lower in the EG compared with the non-EG. Our current findings complement those of previous studies because we found an association between exhaustion status and LSA score even after adjusting for physical function and other covariates.

In the fully adjusted multivariate regression analysis, self-reported exhaustion was independently associated with decreased life space but not with gait speed or gait endurance. Considering the effect of exhaustion on the capacity

of energy in the physical activity cycle, older adults cease to perform activities that are not necessary for daily life to prevent exhaustion[9]. In the present study, expanding the life space may not be as important as maintaining gait function for ADL; thus, older adults with self-reported exhaustion would have incorporated a smaller life space. On the other hand, maintaining gait speed or gait endurance may be considered to be more necessary for daily living for older adults than expanding life space and thus were maintained despite self-reported exhaustion.

In the present study, self-reported exhaustion was not associated with physical function including normal gait speed or the results of the 6WMT. The discrepancy between our results and those of other studies may reflect differences in methodology, although previous studies showed an association between self-reported exhaustion and physical function. Other studies have assessed gait speed using maximum speed[10] and gait endurance using the 400 m walking test[11], whereas our study included a comfortable speed test and the 6MWT, respectively. Another explanation for the discrepancies may relate to the differences in the populations' characteristics. For example, previous studies have sampled older adults between 65 and 102 years of age (mean 75 years)[10] or have targeted only persons of 75 years of age[11], whereas the mean age was 71.7 years in our study. The influence of these variables should be investigated using a similar methodology in future studies.

To our knowledge, our study is the first to report on the association between exhaustion status and life space among older adults with MCI. LSA was developed to evaluate mobility status by measuring the life space for elderly individuals living in a community[22]. However, the LSA score is influenced by physical activity as well as physical performance, ADL, and sociodemographic factors[28]. For example, the life space is sensitive to marginal limitations before an older person experiences difficulties in performing ADL or instrumental ADL[22]. Life space may be a useful identifier of older adults at risk for cognitive decline[29]. In a previous study, life space was related more closely to cognitive function than to physical performance among older adults with amnestic MCI[30]. Self-reported exhaustion has also been reported to be associated with cognitive function[31]. We found that self-reported exhaustion was negatively related to life space among older adults with MCI. Because both a small life space and self-reported exhaustion adversely affect cognitive function, the combination of a small life space and exhaustion may indicate a high risk for cognitive decline. Thus, it may be important to assess not only cognitive function but also self-reported exhaustion for older adults with MCI.

Several limitations in this study should be mentioned. First, the analysis was based on a cross-sectional design, and we were therefore able to examine only the relationships with exhaustion. Second, we did not collect data on other factors that may influence one's feeling of exhaustion such as the cortisol level, which is a biomarker for the "history" of stressful life events[32]. This factor and others should be examined in future studies of exhaustion in older people.

In summary, older adults with MCI who have a restricted life space had self-reported exhaustion. Less life space may lead to several health problems such as disability or dementia in older adults with MCI. Evaluation and preventive strategies to target self-reported exhaustion are recommended to help maintain health status in this population. Future research is needed to identify ways for older people with MCI to improve their exhaustion status.

REFERENCES

1) Petersen RC: Mild cognitive impairment as a diagnostic entity. J Intern Med, 2004, 256: 183–194. [Medline] [CrossRef]
2) Petersen RC, Doody R, Kurz A, et al.: Current concepts in mild cognitive impairment. Arch Neurol, 2001, 58: 1985–1992. [Medline] [CrossRef]
3) Palmer K, Wang HX, Bäckman L, et al.: Differential evolution of cognitive impairment in nondemented older persons: results from the Kungsholmen Project. Am J Psychiatry, 2002, 159: 436–442. [Medline] [CrossRef]
4) Boyle PA, Buchman AS, Wilson RS, et al.: Physical frailty is associated with incident mild cognitive impairment in community-based older persons. J Am Geriatr Soc, 2010, 58: 248–255. [Medline] [CrossRef]
5) Ensrud KE, Ewing SK, Taylor BC, et al.: Comparison of 2 frailty indexes for prediction of falls, disability, fractures, and death in older women. Arch Intern Med, 2008, 168: 382–389. [Medline] [CrossRef]
6) Fried LP, Tangen CM, Walston J, et al. Cardiovascular Health Study Collaborative Research Group: Frailty in older adults: evidence for a phenotype. J Gerontol A Biol Sci Med Sci, 2001, 56: M146–M156. [Medline] [CrossRef]
7) Raji MA, Al Snih S, Ostir GV, et al.: Cognitive status and future risk of frailty in older Mexican Americans. J Gerontol A Biol Sci Med Sci, 2010, 65: 1228–1234. [Medline] [CrossRef]
8) Xue QL, Bandeen-Roche K, Varadhan R, et al.: Initial manifestations of frailty criteria and the development of frailty phenotype in the Women's Health and Aging Study II. J Gerontol A Biol Sci Med Sci, 2008, 63: 984–990. [Medline] [CrossRef]
9) Schrack JA, Simonsick EM, Ferrucci L: The energetic pathway to mobility loss: an emerging new framework for longitudinal studies on aging. J Am Geriatr Soc, 2010, 58: S329–S336. [Medline] [CrossRef]
10) Mänty M, Ekmann A, Thinggaard M, et al.: Fatigability in basic indoor mobility in nonagenarians. J Am Geriatr Soc, 2012, 60: 1279–1285. [Medline] [CrossRef]
11) Vestergaard S, Nayfield SG, Patel KV, et al.: Fatigue in a representative population of older persons and its association with functional impairment, functional limitation, and disability. J Gerontol A Biol Sci Med Sci, 2009, 64: 76–82. [Medline] [CrossRef]
12) Newton JL, Pairman J, Hallsworth K, et al.: Physical activity intensity but not sedentary activity is reduced in chronic fatigue syndrome and is associated with autonomic regulation. QJM, 2011, 104: 681–687. [Medline] [CrossRef]
13) Constant EL, Adam S, Gillain B, et al.: Cognitive deficits in patients with chronic fatigue syndrome compared to those with major depressive disorder and healthy controls. Clin Neurol Neurosurg, 2011, 113: 295–302. [Medline] [CrossRef]
14) Laurin D, Verreault R, Lindsay J, et al.: Physical activity and risk of cognitive impairment and dementia in elderly persons. Arch Neurol, 2001, 58: 498–504. [Medline] [CrossRef]
15) Chen MK: The epidemiology of self-perceived fatigue among adults. Prev Med, 1986, 15: 74–81. [Medline] [CrossRef]
16) Shimada H, Makizako H, Doi T, et al.: Combined prevalence of frailty and mild cognitive impairment in a population of elderly Japanese people. J Am Med Dir Assoc, 2013, 14: 518–524. [Medline] [CrossRef]
17) Folstein MF, Folstein SE, McHugh PR: "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res, 1975, 12: 189–198. [Medline] [CrossRef]
18) Makizako H, Shimada H, Park H, et al.: Evaluation of multidimensional neurocognitive function using a tablet personal computer: test-retest reliability and validity in community-dwelling older adults. Geriatr Gerontol Int, 2013, 13: 860–866. [Medline] [CrossRef]
19) Sheikh JI, Yesavage JA: Geriatric Depression Scale (GDS) recent evidence and development of a shorter violence. Clin Gerontol, 1986, 5: 165–173. [CrossRef]
20) Ensrud KE, Ewing SK, Cawthon PM, et al. Osteoporotic Fractures in Men Research Group: A comparison of frailty indexes for the prediction of falls,