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.

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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; ••: ••–••.**

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]

$$\text{Group A } (n = 70)\text{: ASM} = 0.200 \times (\text{impedance index}) + 0.187 \times (\text{weight}) - 0.878 \left(R^2 = 0.87, \text{SEE} = 1.01 \text{ kg}\right)$$

$$\text{Group B } (n = 71)\text{: ASM} = 0.191 \times (\text{impedance index}) + 0.174 \times (\text{weight}) + 0.816 \left(R^2 = 0.89, \text{SEE} = 0.91 \text{ kg}\right)$$

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

		Ht²/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; Ht²/R, impedance index (height²/resistance) at 50 kHz.

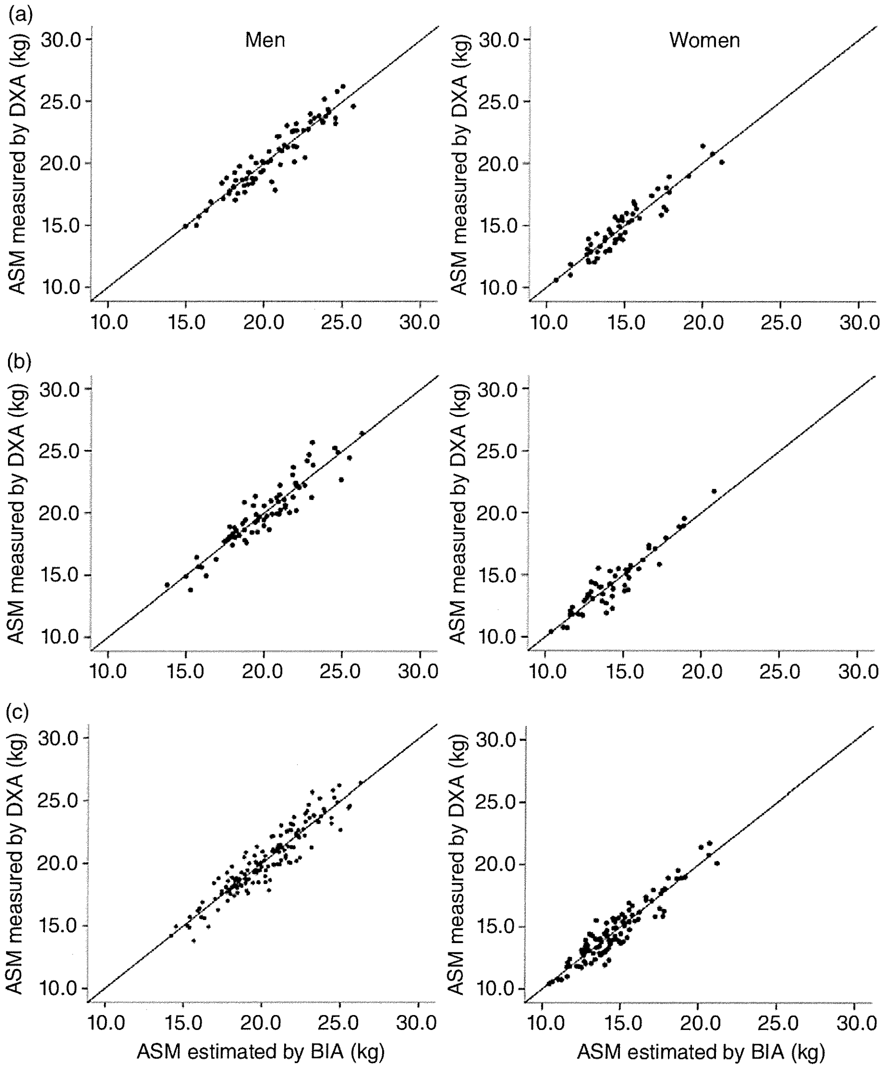

Figure 1 Estimation of appendicular skeletal muscle mass in (a) group A, (b) group B and (c) all participants. Solid line: regression line; dotted line: line of identity. ASM, appendicular skeletal muscle mass; BIA, bioelectrical impedance analysis; DXA: dual-energy X-ray absorptiometry.

[Women]

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

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

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

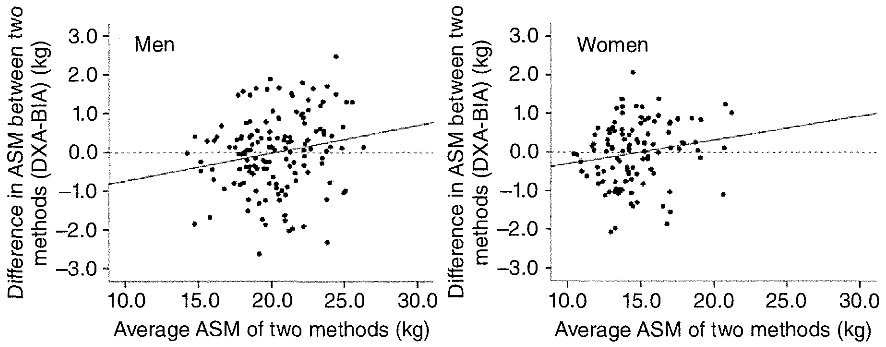

Figure 2 Bland–Altman plot for the difference in appendicular skeletal muscle mass (ASM) between dual-energy X-ray absorptiometry and bioelectrical impedance analysis, and the average ASM of the two methods. Solid line: regression line; dotted line: average difference in ASM between the two methods.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

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ORIGINAL ARTICLE: EPIDEMIOLOGY, CLINICAL PRACTICE AND HEALTH

Relationship between near-infrared spectroscopy, and subcutaneous fat and muscle thickness measured by ultrasonography in Japanese community-dwelling elderly

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Aim: Near-infrared spectroscopy (NIRS) allows estimation of the percentage of body fat (%BF) regardless of the patient's posture; thus, it is useful for assessment of elderly patients with severe decline of basic activity who cannot hold a standing position. However, the accuracy by which the near-infrared light emitted from NIRS reflects subcutaneous tissue is unknown. The aim of this study was to assess how correctly NIRS reflects the subcutaneous fat and muscle thickness derived from ultrasonography in community-dwelling elderly.

Methods: A total of 93 community-dwelling older adults aged 65 years and older were enrolled in this study (mean 75.8 years, 6.7 SD). Participants were assessed according to optical density (OD) measurements by NIRS, subcutaneous fat and muscle thickness by ultrasonography, and muscle strength. Pearson's correlation coefficients were calculated for each sex. Stepwise multiple regression analysis was used to identify factors that contributed to OD for each sex.

Results: OD measured at the forearm and thigh were significantly correlated with subcutaneous fat thickness. In stepwise multiple regression analyses, subcutaneous fat thickness was found to be a significant determinant of OD in men (forearm $\beta = -0.37$, $P = 0.01$; thigh $\beta = -0.63$, $P < 0.001$) and women (forearm $\beta = -0.50$, $P < 0.001$; thigh: $\beta = -0.52$, $P < 0.001$).

Conclusions: These results suggest that NIRS can appropriately estimate fat-free mass. By adding other variables to OD as the predictive variable, skeletal muscle mass might be estimated in the elderly population. **Geriatr Gerontol Int 2013; 13: 351–357.**

Keywords: near-infrared spectroscopy, older adults, sarcopenia, subcutaneous fat thickness, subcutaneous muscle thickness.

Introduction

Sarcopenia is the loss of muscle mass and function related to aging[1–5]. A study reported that older sarcopenic patients are twice as likely to contract infection during a hospital stay compared with older patients with a normal muscle mass.[6] This suggests that sarcopenic individuals might have decreased immunity, which might provide a mechanistic link between sarcopenia and mortality risk. In fact, a low corrected arm muscle area independently predicts long-term mortality in community-dwelling older adults.[7] According to the New Mexico Elder Health Survey, the prevalence of sarcopenia increased from 13% to 24% in persons aged less than 70 years to >50% in persons aged more than 80 years.[8] To achieve successful aging, it is important to preserve a certain amount of muscle mass.

Some researchers recently showed that sarcopenic obese persons are at a particularly high risk for functional impairment and physical disability.[8–11] A previous report suggested that approximately 15% of sarcopenic persons are also obese.[8] Thus, not only muscle mass, but also fat mass, should be accurately assessed in older adults.

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Protein energy malnutrition (PEM) is related to various risk factors (pressure sores, pneumonia, postoperative complications, anemia, loss of bone mineral, femoral neck fracture, cognitive impairment, low activities of daily living, low quality of life and sarcopenia).[12] Furthermore, PEM independently predicts long-term mortality in hospitalized older adults.[13] These individuals should have increased protein consumption, because energy uptake is insufficient in PEM; thus, the body protein (particularly in skeletal muscle) decreases. Therefore, sarcopenic patients might also have PEM. PEM has been reported to be prevalent in hospitalized older adults and nursing home residents,[14–16] whose physical functions often decrease severely. Therefore, body composition should be evaluated in patients with severe decline in physical function.

The most highly accurate method for measuring limb composition is whole-body dual-energy X-ray absorptiometry (DXA).[17] DXA can simultaneously measure body fat mass and bone mineral density. However, whole-body DXA is costly and time intensive. This scan also involves some exposure to radiation. Therefore, the use of bioelectrical impedance analysis (BIA) instruments has gained increasing attention both in the clinic and among the general population. However, few reports have been published about the measurement of body composition in lean elderly patients with severe decline in physical function.

BIA is a non-invasive, portable, quick and inexpensive method for measuring body composition.[18] It is the most common method for measuring body composition in Japan. However, many BIA instruments require patients to maintain a standing position for the measurement. Therefore, BIA instruments are often not used for elderly patients with severe decline in basic activity who cannot hold a standing position. Another method that might have potential for use in older adults is near-infrared spectroscopy (NIRS). NIRS is also a non-invasive, portable, simple and rapid method for assessing the percentage of body fat (%BF). The NIRS instrument allows estimating a patient's %BF simply by placing the tip of the probe against the center of the front side of the arm, regardless of the patient's posture.

Some reports showed that NIRS has a high reliability and accuracy in assessing %BF.[19–22] However, there has been no report on how correctly the near-infrared light emitted from NIRS reflects the subcutaneous tissue, particularly the muscle, at the irradiation point. Therefore, whether NIRS accurately estimates fat and muscle mass is unknown. Regional fat and muscle thickness can be accurately quantified with ultrasonography.[23,24] A previous study reported that the muscle cross-sectional area measured by ultrasonography is related to muscle strength.[25] If NIRS can reflect regional muscle mass, then there might be a relationship between the variable derived from NIRS and muscle strength.

The aim of the present study was to assess how correctly NIRS reflects the subcutaneous fat and muscle thickness derived from ultrasonography in community-dwelling older adults.

Methods

Participants

The participants were recruited from two volunteer databases ($n = 1543$), which included elderly individuals aged 65 years and older who were selected either by random sampling, or from those who attended a health check in Obu City near Nagoya in Japan. Among the 165 participants who responded to the eligibility assessments, 125 completed the strength, NIRS and ultrasound measurements. The inclusion criteria for the present study required that the participants be aged 65 years or older, living independently in the community, Japanese speaking, and with sufficient hearing and visual acuity to participate in the examinations. The exclusion criteria included a history of major psychiatric illness (e.g. schizophrenia or bipolar disorder), other serious neurological or musculoskeletal diagnoses, and clinical depression (Geriatric Depression Scale [GDS] score ≥10). A total of 93 out of 125 participants satisfied the inclusion criteria and were analyzed in the present study.

The present study was approved by the ethics committee of the National Center for Geriatrics and Gerontology. All participants provided written informed consent.

Near-infrared spectroscopy

The NIRS measurements used the Fitness Analyzer BFT-3000 (Kett Science, Tokyo, Japan), the Japanese version of Futrex 5000 (Futrex, Hagerstown, MD, USA), which can estimate body composition.[20,26] This device measures optical densities (OD) at two wavelengths (OD1 = 937 nm, OD2 = 947 nm). The NIRS instrument was tested immediately before obtaining measurements for each patient by using the optical standard provided with the instrument, which is situated in a flexible light shield to ensure its consistent performance throughout the study.

OD values were obtained at two sites: the forearm (flexor carpi radialis) and thigh (quadriceps). Participants were required to maintain a seated position, with their hands dropped to their sides. A single trained physical therapist carried out the NIRS measurements, which were completed in a few minutes.

Ultrasonography

The Miru Cube ultrasound scanning system (Global Healt, Kanagawa, Japan) with a 6-MHz linear array transducer, a portable instrument developed for measuring subcutaneous fat and muscle thickness outside the clinic,[27] was used for measuring the thicknesses of two kinds of subcutaneous soft tissue: fat and muscle. Measurements were taken in longitudinal directions. Participants were required to maintain a seated position, with their hands dropped to their sides. Scans were taken at the same sites (forearm and thigh) as those in NIRS measurements. A single trained physical therapist carried out the scans, which were completed in a few minutes.

The images were transferred to a computer for quantification. Subcutaneous fat and muscle thicknesses were automatically measured using software for exclusive use.

Muscle strength

Grip strength and isometric knee-extension strength were evaluated. The grip strength was measured using a Smedley-type digital hand dynamometer (model TKK5401; Takei Scientific Instruments, Niigata, Japan). The participants were instructed to apply as much hand-grip pressure as possible with their dominant hand in a standing position.

Isometric knee-extension strength was tested on a dynamometer (model MDKKS; Molten, Hiroshima, Japan). For the knee extension test, the right leg was used unless contraindicated by pain or a history of joint replacement. Knee extension was measured while the participant was sitting (knee joint angle of 90°) on a chair by placing a strap around the leg just proximal to the ankle joint. In two experimental trials, the participant pulled against the strap assembly with maximal force; the greatest force was recorded. Isometric knee-extension torque was normalized against the moment arm and body mass (N m/kg) in the data analysis.

Statistical analysis

Student's *t*-tests were used to compare the demographic data, OD, subcutaneous soft tissue thicknesses, and muscle strengths between men and women.

Pearson's correlation coefficients were calculated for each sex to assess simple relationships between OD and subcutaneous soft tissue thicknesses or strengths. Stepwise multiple regression analysis was used to identify factors that contributed to OD for each sex and each measurement site (forearm or thigh). Because there were high correlation coefficients between OD1 and OD2 ($r > 0.969$) and all correlation coefficients were higher at OD1 than at OD2, OD1 was used as the representative value. For the analysis of variables measured in the forearm, OD1 in the forearm was considered the dependent variable, and subcutaneous soft tissue thicknesses in the forearm and grip strength were considered independent variables. For the analysis of variables measured in the thigh, OD1 in the thigh was considered the dependent variable, and subcutaneous soft tissue thicknesses in the thigh and knee-extension strength were considered independent variables.

We considered a value of 5% to be significant. We analyzed the data using IBM SPSS Statistics version 19 for Windows (SPSS, Chicago, IL, USA).

Results

The mean (SD) age of all participants was 75.8 years (6.7). Table 1 summarizes the characteristics and the sex differences of the participants.

The correlation coefficients between subcutaneous soft tissue thicknesses or strengths and each OD value are listed in Table 2. In both men and women, subcutaneous fat thickness in the forearm was significantly correlated with OD in the forearm or the thigh (both OD1 and OD2). In men, subcutaneous fat thickness in the thigh was significantly correlated with OD in the forearm or the thigh (both OD1 and OD2). In women, subcutaneous fat thickness in the thigh was significantly correlated with OD in the thigh (both OD1 and OD2). In men, knee-extension strength was significantly correlated with OD in the forearm (both OD1 and OD2). In the correlation analysis between subcutaneous fat thickness and OD value, all correlation coefficients were higher at OD1 than at OD2 (Figure 1).

In stepwise multiple regression analyses, subcutaneous fat thickness was found to be a significant determinant of OD1 in men (forearm $\beta = -0.37$, $P = 0.01$; thigh $\beta = -0.63$, $P < 0.001$) and women (forearm $\beta = -0.50$, $P < 0.001$; thigh $\beta = -0.52$, $P < 0.001$; Table 3).

Discussion

The power with which light enters the body is called penetrability. The penetrability of light is proportional to the wavelength. Electromagnetic waves with a short wavelength, such as visible light or near-infrared light, have low penetrability and can only warm the surface of the skin. The NIRS instrument used in the present study also measures the amount of subcutaneous soft tissue by means of such near-infrared light; thus, the light might not reach a deep subcutaneous point. A previous study reported that the deviation in optical path length in NIRS becomes large when there is a big difference in the skinfold thickness among participants.[28]

A previous study showed that the distances from the skin surface to muscle measured using an ultrasonography image scanner were 1.0–2.5 cm in participants whose body mass index was 20–24.[29] The NIRS instrument has been used to measure subcutaneous soft

Table 1 Participants' demographic information

Variables	Total $n = 93$	Men $n = 50$	Women $n = 43$	P-value
Age (years)	75.8 (6.7)	76.0 (6.5)	75.7 (6.9)	0.84
Height (cm)	154.6 (8.4)	159.9 (5.6)	148.4 (6.7)	<0.001
Weight (kg)	55.9 (8.7)	58.6 (7.8)	52.7 (8.6)	<0.001
BMI (kg/m^2)	23.3 (2.8)	22.9 (2.6)	23.8 (3.0)	0.10
OD (log1/I)				
Forearm				
OD1	1.090 (0.118)	1.138 (0.107)	1.036 (0.104)	<0.001
OD2	1.122 (0.108)	1.163 (0.099)	1.074 (0.096)	<0.001
Thigh				
OD1	1.036 (0.099)	1.059 (0.102)	1.010 (0.087)	0.01
OD2	1.100 (0.087)	1.114 (0.091)	1.084 (0.079)	0.10
Subcutaneous thicknesses (mm)				
Forearm				
Fat	4.7 (1.7)	4.4 (1.4)	5.0 (1.9)	0.09
Muscle	30.2 (3.0)	31.6 (2.4)	28.5 (2.7)	<0.001
Thigh				
Fat	6.6 (2.7)	5.8 (1.5)	7.5 (3.3)	<0.01
Muscle	18.9 (5.1)	18.7 (4.3)	19.0 (5.9)	0.75
Grip strength (kg)	25.6 (8.1)	30.8 (5.9)	19.6 (5.9)	<0.001
Knee-extension strength (N m/kg)	1.007 (0.381)	1.145 (0.347)	0.847 (0.356)	<0.001

Values are mean (SD). BMI, body mass index; OD, optical density; OD1, optical density at 937 nm; OD2, optical density at 947 nm.

Table 2 Correlation coefficients between subcutaneous thicknesses or strengths and each optical density value

	Forearm OD1	OD2	Thigh OD1	OD2
Men ($n = 50$)				
Subcutaneous thickness				
Fat in the forearm (mm)	−0.37**	−0.30*	−0.32*	−0.28*
Muscle in the forearm (mm)	−0.02	0.03	−0.01	0.04
Fat in the thigh (mm)	−0.38**	−0.35*	−0.63***	−0.58***
Muscle in the thigh (mm)	0.00	0.07	−0.05	−0.03
Grip strength (kg)	0.24	0.23	0.13	0.14
Knee-extension strength (N m/kg)	0.33*	0.35*	0.08	0.12
Women ($n = 43$)				
Subcutaneous thickness				
Fat in the forearm (mm)	−0.50***	−0.44**	−0.48**	−0.48**
Muscle in the forearm (mm)	−0.10	−0.08	−0.12	−0.09
Fat in the thigh (mm)	−0.28	−0.26	−0.51***	−0.45**
Muscle in the thigh (mm)	−0.25	−0.23	−0.12	−0.03
Grip strength (kg)	0.09	0.09	0.10	0.14
Knee-extension strength (N m/kg)	0.13	0.15	0.01	0.01

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$. OD, optical density; OD1, optical density at 937 nm, OD2, optical density at 947 nm.

tissue at a depth of 1.0–2.5 cm from the skin surface.[30] In the participants of the present study, the mean values of subcutaneous fat thickness were 7.2 mm (forearm of men), 8.8 mm (thigh of men), 8.8 mm (forearm of women), and 16.1 mm (thigh of women); the mean values of subcutaneous muscle thickness were 31.6 mm (forearm of men), 18.7 mm (thigh of men), 28.5 mm (forearm of women) and 19.0 mm (thigh of women).

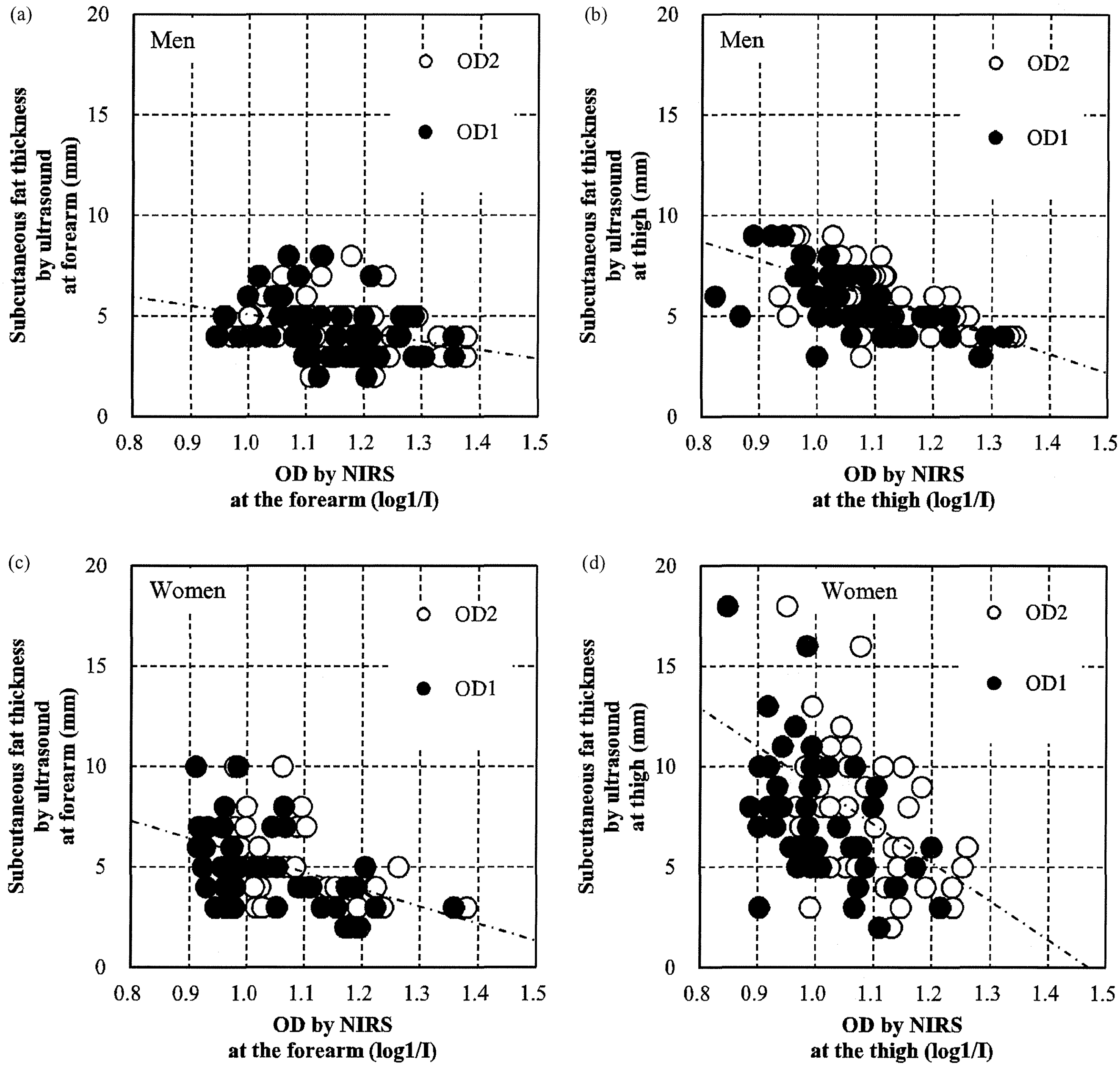

Figure 1 Scatter plot graphs showing the correlation between the subcutaneous fat thickness measured by ultrasound and the optical density (OD) from near-infrared spectroscopy (NIRS). (a,b) Data for men. (c,d) Data for women. Straight lines represent the regression line of OD at 937 nm (OD1), and broken lines represent the regression line of OD at 947 nm (OD2).

These results suggest that the near-infrared lights used in the present study did not reach the deepest point of the subcutaneous muscle layer of the participants. They also suggest that there was no significant correlation between OD and subcutaneous muscle thickness, although there were significant correlations between OD and subcutaneous fat thickness. In the stepwise multiple regression analysis, only subcutaneous fat thickness was included as a significant independent variable relevant to the OD value, and subcutaneous muscle thickness was excluded. Therefore, the estimation of muscle mass by NIRS is interpreted as lacking construct validity. However, this implies the opposite interpretation that the estimation of fat mass by NIRS has sufficient construct validity.

A two-component model dividing the human body into fat mass and fat-free mass is used when considering body composition at the molecular level.[31] This two-component model was the foundation of many methods for estimating body composition developed in the past. In this model, the construct validities for estimation of the fat mass and the fat-free mass are equally sufficient.

Table 3 Determinants of optical density at 937 nm in men and women

Independent variable	Men (n = 50)		Women (n = 43)	
	β	*P*-value	β	*P*-value
Forearm				
Entered				
Thickness of subcutaneous fat	−0.37	0.01	−0.50	<0.001
Removed				
Age	−1.33	0.19	−1.00	0.32
Thickness of subcutaneous muscle	−0.53	0.60	0.46	0.64
Grip strength	1.65	0.11	1.11	0.27
Thigh				
Entered				
Thickness of subcutaneous fat	−0.63	<0.001	−0.52	<0.001
Removed				
Age	−1.12	0.27	−0.62	0.54
Thickness of subcutaneous muscle	−0.02	0.99	−0.24	0.81
Knee-extension strength	0.79	0.43	0.33	0.74

Standardized beta values represent the correlation between optical density at 937 nm and each independent variable. OD, optical density; OD1, optical density at 937 nm.

Therefore, the results of the present study suggest that estimation of fat-free mass by using OD from NIRS has sufficient construct validity. When body composition is considered at the tissue level, the skeletal muscle is known to make up most of the fat-free mass.[31]

However, no significant correlation was found between OD and muscle strength in the present study. This suggests that the variable derived from NIRS is not the only index for estimating fat-free mass. A previous study has shown that there is a relationship between lean body mass and strength.[32] Furthermore, one report[33] suggested that the coefficient of determination became highest when the factors of maximum grip strength and physical performance were added as independent variables in the multiple linear regression model wherein lean mass was the dependent variable (adjusted for age, height, fat mass and activity) A high accuracy might be achieved if the muscle mass is determined by a multivariable estimation that includes OD plus physique indexes (such as height and fat mass), age and activity as independent variables.

To appropriately evaluate sarcopenia, it is ideal to directly measure the whole body skeletal muscle mass. However, it is very difficult to directly measure the body composition of a living human being; thus, an estimation is usually used. Because sarcopenia is related to critical risk factors, body composition needs to be estimated with high accuracy. If the body compositions of a population comprising various body forms are estimated from a single variable, great differences between the true values and the predicted values will be inevitable. Therefore, two or more variables should be used for estimation of body composition. For estimating body composition by using several variables, NIRS, which can appropriately estimate fat-free mass, might be an effective tool.

The present study was limited by all participants having a normal physique. In addition, we did not confirm the predictive validity, because the design of the present study was cross-sectional. Thus, the validity of the method should be confirmed by using longitudinally monitored populations including both thin and obese participants.

In conclusion, the OD value obtained by NIRS was strongly related to subcutaneous fat thickness. This result suggests that NIRS can appropriately estimate fat-free mass. If other variables are added to the OD as the predictive variable, skeletal muscle mass might be estimated with high accuracy in the elderly population.

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ORIGINAL ARTICLE: BEHAVIORAL AND SOCIAL SCIENCES

Effects of exercise and tea catechins on muscle mass, strength and walking ability in community-dwelling elderly Japanese sarcopenic women: A randomized controlled trial

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Aim: To investigate the effects of exercise and/or tea catechin supplementation on muscle mass, strength and walking ability in elderly Japanese women with sarcopenia.

Methods: A total of 128 women aged over 75 years were defined as sarcopenic and randomly assigned into four groups: exercise and tea catechin supplementation ($n = 32$), exercise ($n = 32$), tea catechin supplementation ($n = 32$) or health education ($n = 32$). The exercise group attended a 60-min comprehensive training program twice a week and the tea catechin supplementation group ingested 350 mL of a tea beverage fortified with catechin daily for 3 months. Body composition was determined by bioelectrical impedance analysis. Interview data and functional fitness measurements, such as muscle strength, balance and walking ability, were collected at baseline and after the 3-month intervention.

Results: There were significant group × time interactions observed in timed up & go ($P < 0.001$), usual walking speed ($P = 0.007$) and maximum walking speed ($P < 0.001$). The exercise + catechin group showed a significant effect (odds ratio 3.61, 95% confidence interval 1.05–13.66) for changes in the combined variables of leg muscle mass and usual walking speed compared with the health education group.

Conclusions: The combination of exercise and tea catechin supplementation had a beneficial effect on physical function measured by walking ability and muscle mass. **Geriatr Gerontol Int 2013; 13: 458–465.**

Keywords: exercise, muscle mass, physical function, sarcopenic women, tea catechin supplementation.

Introduction

It is generally accepted that aging is associated with a progressive decline of lean body mass, and muscle mass in particular. This involuntary loss of skeletal muscle mass and strength, defined as sarcopenia, has been associated with loss of independence, diminished quality of life, physical disability, increased risk for falls, mobility impairments, high healthcare burden and medical needs, and mortality in the elderly.[1,2] Hence, prevention and treatment of sarcopenia is very important and necessary for the well-being of the growing elderly population. Although there are several methods of treatment that have being researched, skeletal muscle disuse or inactivity has been considered potentially preventable with targeted interventions.[3,4] Resistance exercise is considered the cornerstone of sarcopenia[5] management, as its beneficial effects in increasing muscle mass and strength have been confirmed in previous studies.[6–8]

Furthermore, several studies have investigated the treatment effects of green tea beverages abundant in tea catechins (TC), a chemical anti-oxidant,[9–11] as a potential nutritional supplementation for elderly adults; however, the results are controversial. Previous studies have suggested that TC have many health benefits for different disorders varying from cancer to weight loss.[9,11] Research on TC, and its effects on age-related declines in functional fitness and muscle mass in humans are scarce, and the mice studies available show inconsistent evidence. One study investigated the combined effects of exercise and TC ingestion in mice, and found that concomitant TC ingestion with habitual exercise is beneficial for suppressing age-related declines in physical

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performance,[10] focusing on endurance exercise. Nevertheless, there are few, if any, randomized controlled trials on the effects of exercise and TC supplementation on basic physical function in elderly people.

The purpose of the present study was to investigate the effects of exercise and/or TC ingestion on muscle mass, strength and walking ability in sarcopenic women.

Methods

Study population

Invitation letters were mailed to 1472 people aged 75 years and older who were randomly selected from the Basic Resident Register of elderly people residing in the Itabashi ward of Tokyo, Japan. There were 1355 responses to the invitation letters, where 1094 people agreed to participate and 261 people refused or did not respond. The baseline assessment was carried out at the Tokyo Metropolitan Institute of Gerontology (TMIG) between October and November 2009, where 974 participated and 120 who had initially agreed to participate were absent.

We operationally defined sarcopenic women based on categorization into at least one of the following inclusion criteria: (i) appendicular skeletal muscle mass/height^2 less than 6.42 kg/m^2 and knee extension strength less than 1.01 Nm/kg ($n = 99$);[12,13] (ii) appendicular skeletal muscle mass/height^2 less than 6.42 kg/m^2 and usual walking speed less than 1.10 m/sec ($n = 21$);[14] (iii) body mass index (BMI) less than 22 and knee extension strength less than 1.10 Nm/kg ($n = 130$); and (iv) BMI less than 22 and usual walking speed less than 1.10 m/sec ($n = 16$). Out of 974 people, 266 (27.3 %) participants were operationally defined as sarcopenic (Fig. 1).

Participants for the interventions were recruited from 266 sarcopenic women. Exclusion criteria included: (i) severe knee or back pain; (ii) severely impaired mobility; (iii) impaired cognition (Mini-Mental State Examination [MMSE] score <24);[15] (iv) missing baseline data; and (v) unstable cardiac conditions. A total of 138 participants (51.9%) were excluded from the study based on the exclusion criteria, or declined participation. The present study protocol was approved by the Clinical Research Ethics Committee of TMIG. The intervention procedures were fully explained to all participants and written informed consent was obtained.

Randomized group assignment

After the baseline assessment, computer-generated random numbers were assigned to 128 participants, who were then sorted and equally divided into four groups, and any variable that identified individual information was not included in the randomization process. The groups were randomly assigned to one of the four interventions: exercise and tea catechin supplementation (Ex + TC; $n = 32$), exercise (Ex; $n = 32$), tea catechin supplementation (TC; $n = 32$) or health education (HE; $n = 32$) groups. The allocation sequence was concealed from the study coordinator, and data collection was carried out by separate physical therapy staff members who were also blind to the allocation of treatments.

Outcome measures

Data were collected at baseline and after the 3-month intervention. Measures included interview surveys, body composition assessments and physical function tests. Measurements of height and weight were used to calculate BMI (kg/m^2).

Interview survey

Each participant was interviewed face-to-face to assess the individual's history of falls, fear of falling, pain, exercise habits, urinary incontinence, frequency of going out, self-rated health and so on.

Body composition assessment

Percent body fat, lean body mass, and total and segmental muscle mass were measured using a multifrequency bioelectrical impedance analysis (BIA) instrument that operated at frequencies of 5, 50, 250 and 550 kHz (Well-Scan 500; Elk, Tokyo, Japan). The participants stood on two metallic electrodes on the scales of the BIA instrument barefoot, holding two metallic grip electrodes placed in the palm of each hand with the fingers wrapped around the handrails. Segmental muscle mass values of each leg, arm and the trunk were measured and added to obtain appendicular skeletal muscle mass and leg muscle mass.

Performance measures

The performance measures included muscular strength (grip strength, knee extension strength), walking ability (usual and maximum walking speed, and timed up & go [TUG]) and balance ability (one leg standing time with eyes open). For the TUG test, time was measured in seconds from the time the participants stood up from a straight-backed chair placed against a wall, walked 3 m toward a cone as quickly and safely as possible, walked around the cone, and sat down on the chair again.[16] Assistive walking devices were allowed in measures of walking speed and TUG only if they expressed concerns about walking without a device, or if the investigators believed there was a danger of falling. Knee extension strength was measured twice, and the higher value

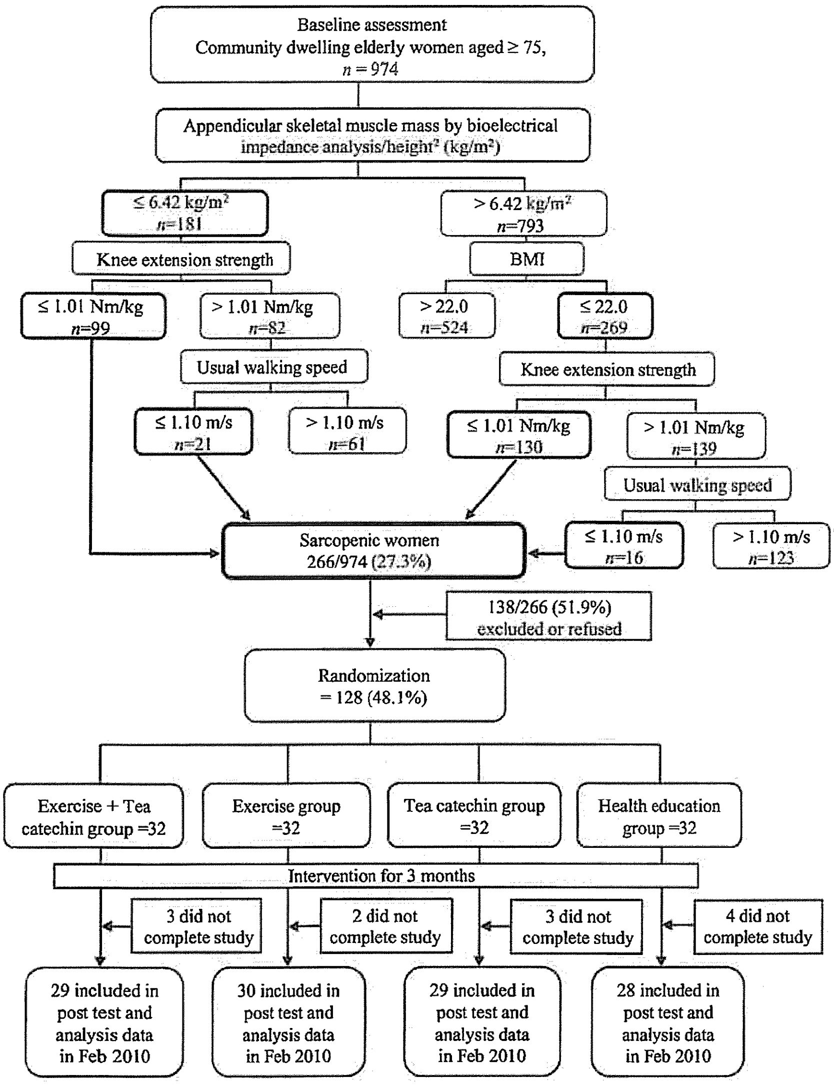

Figure 1 Algorithm for the selection of women operationally defined as sarcopenic, and flowchart of participants in the randomized controlled trial of exercise and tea catechin supplementation. BMI, body mass index.

divided by bodyweight (Nm/kg) was analyzed. Detailed procedures for the performance measures have been described previously.[17]

Intervention

Exercise

The exercise consisted of stretching, muscle strengthening, balance and gait training of moderate intensity maintained at approximately 12–14 on the Borg Rate of Perceived Exertion scale.[18] Each class was 60 min, held at the TMIG twice per week for 3-months. To ensure proper instruction to all participants, the two exercise intervention groups were divided into four subgroups, where the participants exercised together within their assigned subgroup in one of four exercise sessions offered per day.

The exercise session included a 5-min stretching warm-up of the neck, shoulders, lower back, hips, knees and ankles, 30-min of strengthening exercises, 20 min of balance and gait training, followed by a 5-min cool-down.

Muscle strength training

Strengthening exercises were carried out in a progressive sequence from the seated position, which initially provided a secure and stable position, to the standing position. Other resistance was applied through use of resistance bands for upper body strengthening and ankle weights for the lower body, as well as increasing the repetitions and sets of the exercises. Participants were initially instructed to complete up to one eight-repetition set of each type of exercise, which gradually increased to 10 repetitions, and up to two sets.

Resistance was increased on a group basis when the participants were able to execute each exercise without loss of proper execution. Each individual's ability to increase intensity was assessed by the principal investigator, the exercise instructor and assistant trainers.

To strengthen lower extremities, a fixed weight was placed on the ankle during the exercises. Weights of 0.50 kg, 0.75 kg, 1.00 kg, and 1.50 kg were prepared and used in accordance with each participant's strength level as the resistance progressively increased. Strengthening of the leg muscles focused on hip extensors and adductors, knee flexors and extensors, and ankle dorsi- and plantarflexors.

Gait and balance training

The participants practiced various walking patterns, focusing on stability maintenance during walking. Participants were taught to focus their attention on increasing toe elevation of the forward leg, heel elevation of the rear limb, and stride length through gait exercises including walking with directional changes and weight shifting. The balance training contained exercises, such as one-leg stands, tandem stand and tandem walking, for each participant to train their static, dynamic and lateral balancing ability.

Tea catechin supplementation

Bottles containing 350 mL of tea fortified with 540 mg of catechin were provided for the participants in the TC supplementation group every 2 weeks. The participants were instructed to drink one bottle per day, every day for 3 months. To monitor their TC intake accurately, the participants were asked to record the volume of tea consumed (the whole bottle, half the bottle, or about one-quarter) on record sheets that were collected every 2 weeks, along with the bottle caps of finished bottles. Participants who drank at least 54 bottles or more out of the 90 bottles (60%) were considered to have completed the supplementation intervention.

Health education

The HE group served as the control group, and the participants took a class once a month for 3 months, a total of three times. Health professionals taught topics such as cognitive function, the long-term care system and oral hygiene. No specific instructions on diet or physical activity were given, and the participants were asked to continue their regular lifestyle habits.

Data analysis

Differences in baseline measures between the groups were measured using a one-way analysis of variance (ANOVA), and χ^2-tests were carried out on categorical variables. Two-way repeated-measures ANOVA was used to analyze differences in the effect of the intervention on outcome measures between groups, and a post-hoc test was carried out where significant P-values (<0.05) were found to determine which groups were significantly different. Percentage changes in leg muscle mass and strength, and walking ability postintervention were calculated using the formula: % change = ((postintervention value − baseline value) / baseline value) × 100. To compare the effects of the four intervention groups on combined variables of leg muscle mass and functional fitness after 3 months of intervention, multiple logistic regressions were carried out. All analyses were carried out using SPSS software, Windows version 19.0 (SPSS, Tokyo, Japan) and SAS, version 9.2 for Windows (SAS Institute Japan, Tokyo, Japan).

Results

All of the baseline characteristics including age, percent body fat, muscle mass, walking speed, urinary incontinence and falls were similar between the groups (Table 1).

In comparing the pre- and postintervention changes in performance measures and body composition by two-way repeated-measures ANOVA (Table 2), there were significant group × time interactions in TUG ($F = 15.408$, $P = 0.005$), usual walking speed ($F = 4.327$, $P = 0.007$) and maximum walking speed ($F = 15.161$, $P < 0.001$), where the changes in the Ex + TC group were greater than the HE group.

Figure 2 shows the within group analyses of percent changes from pre- to postintervention. Leg muscle mass significantly increased in the Ex + TC group (2.21%, $P = 0.016$), whereas only small changes in the other groups were observed. Usual walking significantly increased in the Ex + TC group (11.36%, $P = 0.010$), a modest increase was seen in the Ex group (4.84%, $P = 0.020$), and slight decreases were observed in the TC and HE groups.

The multiple logistic regression analysis showed that the Ex + TC group had a significant effect on the combined variables of increased leg muscle mass and improved usual walking speed (OR 3.61, 95% CI 1.05–13.66; Table 3). The OR for increased leg muscle mass and knee extension strength in the Ex + TC group, although statistically non-significant, were more than twofold as great as the Ex or TC only groups.

Discussion

Although sarcopenia was originally defined as the age-related loss of muscle mass,[19] muscle strength does not depend solely on muscle mass, and the relationship