Prevalence of Sarcopenia Estimated Using a Bioelectrical Impedance Analysis Prediction Equation in Community-Dwelling Elderly People in Taiwan

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OBJECTIVES: To compare a bioelectrical impedance analysis (BIA) prediction equation for estimating skeletal muscle mass (SM) with magnetic resonance imaging (MRI)-measured SM and to investigate the prevalence of sarcopenia in community-dwelling elderly people in Taiwan.

DESIGN: Cross-sectional survey.

SETTING: Communities in the district of Zhongzheng, Taipei.

PARTICIPANTS: Forty-one volunteers (aged 22–90) for BIA equation validation; 302 individuals aged 65 and older and 200 adults aged 18 to 40 for the investigation of the prevalence of sarcopenia.

MEASUREMENTS: Skeletal muscle mass was estimated using a BIA prediction equation and measured using MRI.

RESULTS: No statistical difference between MRI-measured and BIA-derived SM was observed (difference of -0.44 ± 1.55 kg, $P = .08$). The prevalence of sarcopenia in was 18.6% in elderly women and 23.6% in elderly men.

CONCLUSION: Estimation of SM using a BIA equation was validated in Taiwanese volunteers. It was confirmed that sarcopenia is an emerging health problem in the aging population in Taiwan. **J Am Geriatr Soc 56:1710–1715, 2008.**

Key words: aging; skeletal muscle; bioelectrical impedance analysis; sarcopenia; magnetic resonance imaging

Sarcopenia refers to the loss of skeletal muscle mass (SM) and decline in associated muscular function with aging.[1–3] The prevalence of sarcopenia in white and Hispanic people has been reported to increase rapidly with aging.[4–6] Sarcopenia has been reported to be significantly associated with functional impairment and disability in elderly people.[7–9] In addition, the estimated direct healthcare cost attributable to sarcopenia in the United States was $18.5 billion in 2000.[10] However, there has been no systematic study of sarcopenia in Taiwan.

Investigations of sarcopenia have rekindled interest in quantifying changes in SM. Fat free mass (FFM) has traditionally been used as a surrogate measure of muscle mass, although it does not always accurately reflect differences in muscle mass between individuals.[11] The percentage of FFM that is appendicular SM varies among individuals and declines with aging.[12,13] There is solid evidence from cadaver studies that magnetic resonance imaging (MRI) and computerized tomography (CT) provide precise and reliable measurements of SM and thus can be considered as criterion methods for measuring SM in vivo,[14–16] but cost, accessibility, and the problem of radiation exposure limit the use of whole-body imaging. Recently, dual-energy X-ray absorptiometry (DEXA) has become an attractive alternative method for SM estimation.[17,18] Nevertheless, all the methods described above are poorly accessible for a large-scale, community-based investigation.

During the past 2 decades, the use of bioelectrical impedance analysis (BIA), which is based on measuring tissue conductivity in the study of human body composition, has grown rapidly.[19–21] Because SM is the largest tissue component of body mass and is an electrolyte-rich tissue with low resistance, it is a dominant conductor. One study developed a prediction equation for estimating whole-body SM using BIA measurement.[22] BIA is a simple, noninvasive, inexpensive method that should be practical and suitable for field studies, but that study's equation was derived from white people and was reported to be applicable to Hispanic and African-American people but has not been validated for the estimation of SM in Asian populations. For the application of this useful prediction equation for surveying sarcopenia in Asians, this equation should be validated in Asians.

As in other developed countries, the proportion of elderly people in Taiwan now constitutes more than 10% of

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the total population.[23] Understanding the effect of sarcopenia on elderly Taiwanese is essential for the development of health promotion programs. The purposes of this study were to validate the BIA prediction equation for estimating SM by comparing it with MRI-measured SM and to investigate the prevalence of sarcopenia in community-dwelling elderly people in Taiwan.

METHODS

Design and Participants

A cross-sectional survey to determine the prevalence of sarcopenia in a Taiwanese community was conducted in three steps. First, 41 volunteers (aged $\geq$18) were recruited from the neighborhood surrounding Taipei city to undergo BIA and MRI measurements to validate the prediction equation for estimating SM. None of the subjects had diseases, nor were they taking medications known to affect the study variables, such as hyper- or hypothyroidism, being given any hormone therapy (such as growth hormone), or receiving long-term steroid treatment. Second, the SM prediction equation was applied in the young, healthy adults to establish the normal ranges of SM in Taiwan. Two hundred healthy adults (100 men and 100 women) aged 18 to 40 were recruited through various advertising strategies for BIA measurement to calculate whole-body SM. Finally, the prevalence of sarcopenia in elderly people living in the community was investigated. Posters were displayed, and volunteers were recruited from communities in the district of Zhongzheng, an urban region of Taipei city. Three hundred two individuals (157 men and 145 women) aged 65 and older volunteered for this investigation. Each subject was interviewed using a structured questionnaire to obtain basic demographic data and information on medical conditions necessitating long-term treatment. Information on physical activity habits was obtained from one simple question. If the subject participated in regular physical activity or exercise for more than 30 minutes a day, more than 3 days a week, that individual was considered to be a regular exerciser. Volunteers were excluded if any disease or prescribed medication being taken was known to affect whole-body composition, as previously mentioned. All of the elderly participants were ambulatory without major physical disabilities. Written informed consent was obtained before participation. The National Taiwan University Hospital Ethics Committee approved the protocol for this trial in 2005.

Measures

MRI Procedure and Image Analysis

T_1-weighted, spin-echo sequence MRI scans were acquired using the 1.5-T Signa 5 $\times$ system (General Electric Medical Systems, Milwaukee, WI) with a 210-ms repetition time and a 17-ms echo time to obtain the MRI data. A standard coil was used for radio frequency transmission and reception of the magnetic resonance signal. The MRI protocol used in this study was the same as described in the previous study.[22] The subjects were placed in a supine position in the magnet with their arms straight overhead. The intervertebral space between the fourth and fifth lumbar vertebrae (L_4–L_5) was used as the point of origin, and transverse images (10-mm slice thickness) were obtained every 40 mm from the subjects' hands to feet. This protocol resulted in a total of approximately 39 images (39 $\pm$ 3) for each subject. All images were transferred and displayed on a commercial personal computer workstation for postprocessing analyses using semiautomated three-dimensional image processing software (Amira Software 4.1, TGS Inc., San Diego, CA).

The image files were imported to the software, and image segmentation was performed initially. By using the "image wand" and "brush tool" of the software, tissue area for a given MRI image was identified sequentially. The area of the respective tissues in each image was computed automatically by summing the number of pixels and multiplying by the individual pixel surface area. The volume of each tissue in each slice was calculated by multiplying the tissue area by the slice thickness of 10 mm. The volume of the 40-mm space between two consecutive slices was calculated using a mathematical formula that has been previously described.[15,16] Volume units were converted to mass units by multiplying the volumes by the assumed constant density of adipose tissue–free SM (1.04 kg/L).

Anthropometric Variables and Bioelectrical Impedance Analysis

Body mass and standing height were measured with subjects dressed in light clothing and barefoot. Body mass index (BMI) was calculated as body weight divided by height squared (kg/m^2).

Bioelectrical resistance was measured using a Maltron system (Maltron BioScan 920, Rayleigh, UK) with an operating frequency of 50 kHz at 800 μA. The subjects were supine on a nonconducting surface with their arms abducted away from their trunk and the legs slightly separated for 5 minutes. Four electrodes and cables were attached to the right hand and ankle of the subjects as shown in the user's manual. When the measurements stabilized, the analyzer displayed resistance directly and immediately. According to the strong relationships between measured resistance, FFM, and total body water, many prediction equations were developed to estimate percentage of body fat and FFM, which could also be directly displayed after BIA measurement. The FFM index (FFMI) was calculated as FFM divided by body height squared (kg/m^2). Previous studies evaluating the reliability of BIA measurements indicated that the coefficients of variation ranged from 1.8% to 2.9%.[20,21]

Skeletal muscle mass was calculated using the BIA equation from the previous study:[22]

SM (kg) = [0.401 $\times$ (height^2/resistance) + (3.825 $\times$ gender) $-$ (0.071 $\times$ age) + 5.102], where height is in cm; resistance is in ohms; for sex, men = 1 and women = 0; and age is in years. Absolute SM was converted to an SM index (SMI) by dividing height by meters squared (kg/m^2). Sarcopenia was defined as the SMI of 2 standard deviations (SDs) or more below the normal sex-specific means for young persons.[7]

Statistical Analyses

All data were analyzed using the SPSS for Windows release 11.0 (SPSS Inc., Chicago, IL). Descriptive statistics were used to describe the demographic and measurement variables of all subjects. The Student *t*-test was used to examine the differences in subject characteristics between men and

women. The difference between MRI-measured and BIA-predicted SM was tested using a paired *t*-test. This difference was also plotted against the mean of MRI-measured and BIA-predicted SM to look for systematic differences, as suggested previously.[24] Subgroup analyses for the agreement between BIA-predicted and MRI-measured SM were also performed according to age and sex. The alpha value was set at 0.05.

RESULTS

The 41 volunteers invited for equation validation varied in age (22–90) and BMI (17.6–34.6 kg/m^2) (Table 1). The correlation between SM obtained using a BIA prediction equation and SM measured using MRI was high (Figure 1A); the coefficient of determination and standard error of the estimate (SEE) of the regression equation were 0.95 and 1.56 kg (7%), respectively. The average difference between MRI-measured and BIA-predicted SM was not significant (-0.44 ± 1.55 kg, $P = .08$).

Systematic differences between BIA-predicted and MRI-measured SM were determined using a Bland-Altman plot (Figure 1B). The average difference between BIA-predicted and MRI-measured SM and the mean SM of MRI-measured and BIA-predicted SM showed a small but nonsignificant positive correlation ($r = 0.23$, $P = .15$). The positive slope of the regression of the differences in the means suggests a slight tendency to underestimate SM in individuals with high SM and to overestimate SM in those with low SM. The difference between BIA-predicted and MRI-measured SM was within 5%, 10%, and 15% of the MRI-measured SM for 59% (80% for men and 38% for women), 80% (95% for men and 67% for women), and 93% (100% for men and 86% for women) of the subjects, respectively.

The SMI values in the young men and women were 10.87 ± 1.00 kg/m^2 and 7.88 ± 0.73 kg/m^2, respectively (Table 1). According to the results, sarcopenia was defined as a SMI less than 8.87 kg/m^2 and 6.42 kg/m^2 in men and women, respectively.

The characteristics of the elderly subjects showed that the men were taller and had greater FFM and less fat mass than the women (Table 1), although the SMI was significantly greater for men than for women (9.80 ± 1.14 kg/m^2 vs 7.25 ± 0.95 kg/m^2, $P < .001$). Table 2 shows various prevalences for different indices. Sarcopenia defined using SM/SMI would result in a higher prevalence than FFM/FFMI. When SMI was used to define sarcopenia, the prevalence of sarcopenia was 18.6% in women and 23.6% in men.

DISCUSSION

Sarcopenia is an important concern with aging, but a lack of suitable tools limits large-scale surveys to learn more about this condition. Because MRI, CT, and DEXA are not easily accessible for field surveys, BIA might be a good alternative method to measure SM for epidemiological surveys. The previous study reported that the BIA equation for predicting SM derived from white subjects underpredicted SM in an Asian cohort.[22] It suggested that biological differences between these two races might influence the relationship between resistance and SM. The results of the current study

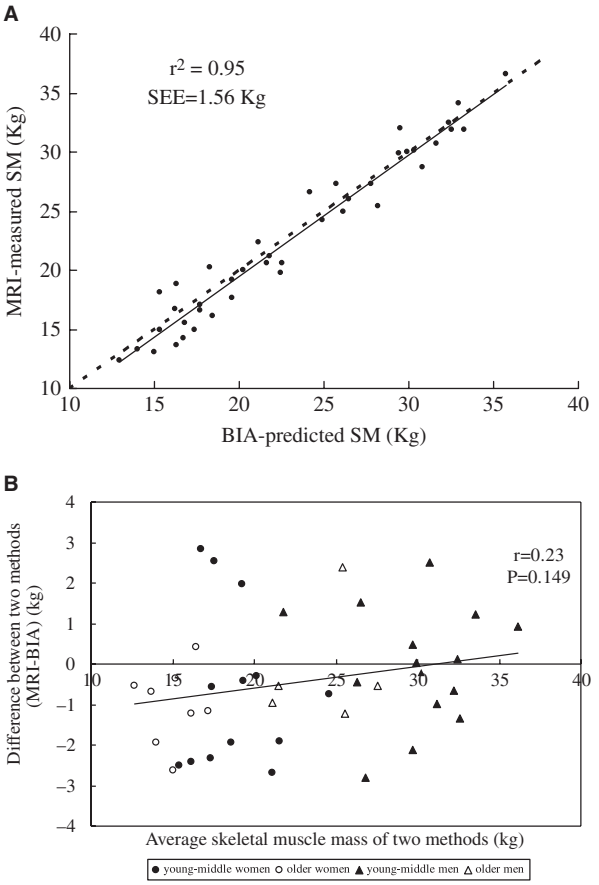

Figure 1. (A) Regression between the bioelectrical impedance analysis (BIA)-predicted and magnetic resonance imaging (MRI)-measured skeletal muscle mass (SM). Solid line, regression line; dotted line, line of identity. (B) Bland-Altman plot for difference between MRI-measured and BIA-predicted skeletal muscle mass and the average skeletal muscle mass of the two methods. r^2 = coefficient of determination; SEE = standard error of the estimate; r = correlation coefficient.

demonstrated a coefficient of determination (0.95) and a magnitude of error (SEE = 1.56 kg) in predicting SM that were similar to those found in the previous report.[22] The low SEE for this predicting equation could be compared with the corresponding SM-prediction model SEEs for DEXA (1.58 kg),[25] method of anthropometry (2.8 kg),[26] and urinary creatinine (1.9 kg).[27] Although the Bland-Altman plot indicated a trend of systematic error with the BIA method, this error was small. The differences between MRI-measured and BIA-predicted SM ranged from +2.84 kg to −2.81 kg in the current study, which was smaller than that between MRI-measured and DEXA-predicted SM reported previously (+4.2 kg to −5.1 kg).[7] These results suggest that the BIA method provided meaningful SM estimation within Asian populations. To ensure that reliable BIA measurements are obtained, hydration status and exercise should be well controlled, although the positive slope of the Bland-Altman plot indicated a trend of overestimation error with the BIA method for participants with lower SM. Most of the elderly women in this study had lower SM. The results improved slightly after the subgroup analysis exclusion of elderly women because there was a positive slope of

Table 1. Characteristics and Anthropometry Data of Validation Group, Reference Group, and Older Adults

Characteristic	Validation Group		Reference Group		Older Adults	
	Men (n = 20)	Women (n = 21)	Men (n = 100)	Women (n = 100)	Men (n = 157)	Women (n = 145)
Age, mean ± SD	45.1 ± 16.7	53.4 ± 18.9	26.7 ± 5.7	27.6 ± 5.9	76.6 ± 7.0	74.4 ± 6.4
Weight, kg, mean ± SD	68.8 ± 8.8	54.4 ± 9.6	69.6 ± 11.3	52.5 ± 6.5	65.5 ± 10.2	56.8 ± 9.5
Height, cm, mean ± SD	167.4 ± 6.7	154.2 ± 5.2	173.1 ± 5.5	160.0 ± 4.7	163.8 ± 7.6	153.0 ± 5.7
Body mass index, kg/m^2, mean ± SD	24.5 ± 2.4	22.9 ± 3.9	23.2 ± 3.5	20.6 ± 2.5	24.4 ± 3.1	24.2 ± 3.7
Percentage of total body fat, mean ± SD	19.8 ± 5.2	27.5 ± 8.8	14.4 ± 5.9	20.5 ± 4.9	23.3 ± 7.3	32.7 ± 8.5
Fat free mass, kg, mean ± SD	55.0 ± 6.5	38.9 ± 4.3	59.1 ± 7.0	41.6 ± 3.6	50.0 ± 7.6	37.8 ± 5.9
Fat free mass index, kg/m^2, mean ± SD	19.6 ± 1.7	16.3 ± 1.1	19.7 ± 1.9	16.3 ± 1.2	18.6 ± 2.0	16.1 ± 2.1
Skeletal muscle mass, kg, mean ± SD						
BIA estimated	28.6 ± 4.2	17.8 ± 3.0	32.6 ± 3.5	20.0 ± 2.2	26.4 ± 3.8	17.0 ± 2.7
MRI measured	28.52 ± 4.3	17.00 ± 3.02				
Skeletal muscle mass index, kg/m^2, mean ± SD						
BIA estimated	10.2 ± 1.2	7.47 ± 1.1	10.9 ± 1.0	7.9 ± 0.7	9.8 ± 1.1	7.3 ± 1.0
MRI measured	10.1 ± 1.2	7.1 ± 1.1				
Morbidity, %						
Cardiovascular diseases					20	22
Pulmonary diseases					10	1
Gastrointestinal diseases					5	3
Orthopedic diseases					20	32
Cancer					4	2
Regular exerciser*					71	43

* Regular exercise was defined as participation in physical activity or regular exercise more than 30 minutes a day, more than 3 days a week.
SD = standard deviation; BIA = bioelectrical impedance analysis; MRI = magnetic resonance imaging.

0.16 ($P = .39$). The prevalence of sarcopenia in elderly women in the current investigation (18.6%) might be underestimated because of overestimation of SM in elderly women. There is a need to recruit more elderly women to modify the prediction equation to fit a Taiwanese population, especially with regard to elderly women.

Table 2. Prevalence of Sarcopenia as Defined According to Different Indices

Age	n	Fat Free Mass	Fat Free Mass Index	Skeletal Muscle Mass	Skeletal Muscle Mass Index
		%			
Men					
65–69	30	23	17	33	20
70–79	80	25	13	43	24
≥80	47	26	11	43	26
Subtotal	157	24	13	42	24
Women					
65–69	35	20	14	37	17
70–79	79	27	13	37	18
≥80	31	39	16	39	19
Subtotal	145	28	14	37	19

Although the prevalence of sarcopenia in elderly people has been broadly investigated in Western countries, there has been only one report on the prevalence of sarcopenia in elderly people in Asian countries, and in this report a low prevalence of sarcopenia was found in Hong Kong (12.3% and 7.6% in Chinese men and women, respectively).[28] This is the first survey of sarcopenia conducted in Taiwan, and the prevalence of sarcopenia was 18.6% and 23.6% in women and men, respectively. Considering that there are more than 2.3 million older Taiwanese,[23] approximately 460,000 older Taiwanese were sarcopenic. Because low SM has been related to physical function,[7–9] many older Taiwanese adults may thus be at greater risk of functional impairment and disability. The prevalence of sarcopenia in the New Mexico Elder Health Survey[7] was 33.9% and 28.5% in women and men, respectively. The results of the current study showed slightly lower prevalence than that reported previously[7] and were more comparable with the results of another community-based survey (22.6% and 26.8% in women and men, respectively),[6] although other studies have reported lower prevalences of sarcopenia, ranging from 6% to 15%.[4,8,28] The differences in results may be mainly due to differences in the definitions of sarcopenia, studied populations, or reference populations.

Investigators in previous studies have adopted similar definitions, making interethnic comparisons feasible. Sarcopenia has been defined as an SMI more than 2 SDs below the mean for young adults according to appendicular SMI

(ASM/Ht^2)[6,7] or total SMI (TSM/Ht^2).[4,8,9,28] The reported prevalence might be different based on the subject recommitment criteria or the study population, such as whole population or only community dwellers. The previous studies[7–9] reported the results from population-based samples. Another study included community-dwelling and institutionalized individuals.[4] The current study included only community-dwelling volunteers who were ambulatory and independent in activities of daily living.[6,28] Physical activity can stimulate an increase in SM. The present study showed that more than 70% of elderly men but only 43% of elderly women participated in regular physical activity. These elderly individuals may be healthier and therefore have a lower prevalence of sarcopenia, but it would be preferable to use other objective measurement tools to evaluate physical activity in future studies.

The different prevalences of sarcopenia also depend on which normative data were used. Because sarcopenia is defined according to normal values for young persons, the lower young reference values result in a lower threshold for diagnosing sarcopenia and thus fewer persons diagnosed with sarcopenia. The mean SMI in young Chinese men in a previous study was approximately 17% lower than that in white subjects.[28] This would result in a lower absolute normal value for diagnosing sarcopenia, and therefore, fewer persons would be diagnosed in a Hong Kong study. Many sarcopenia surveys have used the reference population from the Rosetta study, in which the cutpoints for sarcopenia were set as an SMI less than 5.45 kg/m^2 for women and 7.26 kg/m^2 for men.[12] Another study used cutoff values of 6.0 kg/m^2 in women and 8.70 kg/m^2 in men,[4] but this reference population included subjects younger than 50. The optimal cutpoints associated with high instrumental activity of daily living disability risk in the National Health and Nutrition Examination Survey III study were 5.75 kg/m^2 in women and 8.50 kg/m^2 in men.[9] The young American reference group is perhaps not suitable for developing the criteria for sarcopenia in the Taiwanese population. The cutoff points for sarcopenia in the current study (6.42 kg/m^2 in women and 8.87 kg/m^2 in men) were higher than that of the Rosetta reference group[12] and more comparable with those in another group.[4] Using cutoff values established previously,[9] in the prevalence of sarcopenia in the current study was 2.8% for women and 11.5% for men. In contrast, using the definition of sarcopenia as defined previously,[4] the prevalence of sarcopenia in the current study was 5.5% for women and 15.9% for men. As previously mentioned, these two studies were population-based surveys that might show a higher prevalence of sarcopenia than the current study using the same cutoff points.

The small number of subjects and its cross-sectional nature limited the present analysis. Because the participants were recruited using posters and telephone invitations in a city district, it might include more elderly people with good willingness and activity levels and fewer frail older individuals with low SM, thereby leading to a conservative bias in the estimated prevalence of sarcopenia, although elderly people with chronic diseases or prescribed medications were not excluded, as previously mentioned. An additional potential bias was that sarcopenia might be associated with a greater risk of death so that survivors represent a less-affected subset of the general population.

CONCLUSION

This is the first investigation of sarcopenia in community-dwelling elderly people in Asian countries using a BIA prediction equation. Despite the potential aforementioned concerns, the cross-validation of a BIA equation for predicting SM was successful, and the magnitude of the error in predicting SM using BIA was small. These observations suggest that BIA can provide accurate estimates of SM in adult populations. The study also demonstrated that the prevalence of sarcopenia is approximately 20% in independent community-dwelling older adults in Taiwan. This result confirms that sarcopenia is an emerging health problem in aging Asian populations. Prospective studies are needed to delineate the natural progression and predisposing factors of this condition.

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