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Assessment of appendicular skeletal muscle mass by bioimpedance in older community-dwelling Korean adults

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ABSTRACT

It is crucial to investigate age-related body composition changes in geriatric medicine. Bioelectrical impedance analysis (BIA) is easy to perform, non-invasive, relatively inexpensive, and portable. However, the accuracy of measurement by BIA is questionable. To develop and cross-validate the predictive equation for estimated appendicular skeletal muscle mass (ASM) using BIA in older community-dwelling Korean adults, we include two cohorts: study participants aged 65–80 years in the Ansung cohort for the Korean Health and Genome Study (men, $n = 285$; women, $n = 435$) used as equation-generating group, and Korean Longitudinal Study of Health Aging (KLoSHA) as cross-validation group (men, $n = 202$; women, $n = 208$). Dual energy X-ray absorptiometry (DXA) and BIA were performed in both cohorts. Using multiple linear regression analysis, we drew a predictive equation for DXA-measured ASM by BIA resistance. From DXA and BIA measurements in the Ansung cohort, we generated the estimated equation ASM (kg) = $[(\mathrm{Ht}^2/R \times 0.104) + (\mathrm{age} \times -0.050) + (\mathrm{gender} \times 2.954) + (\mathrm{weight} \times 0.055)] + 5.663$ where Ht is height in centimeters; R is BIA resistance in 250 Ω; for gender, men = 1 and women = 0; and age is in years. We validated this equation in the KLoSHA. The r^2 of the estimated ASM was 0.890. This BIA equation provides valid estimates of ASM in older Korean adults.

1. Introduction

Sarcopenia, which is defined as low muscle mass and muscle strength, is becoming a major concern in the aging society. The criteria of sarcopenia were mainly based on appendicular skeletal muscle mass (ASM) measured by dual energy X-ray absorptiometry (DXA) (Baumgartner, 2000; Cruz-Jentoft et al., 2010). However, DXA is not widely available to apply to the large-scale population studies or clinical practice due to cost, portability and a small risk of radiation exposure. Recently, bioelectrical impedance analysis (BIA) has been widely used in assessing body composition using the resistance to an electric current (Ellis, 2000). BIA is easy to perform, non-invasive, relatively inexpensive, and portable. However, it is influenced by hydrated status, extremes of body mass index (BMI) and illness. Therefore, the accuracy of measurement by BIA is questionable.

A previous study developed a prediction equation for whole-body skeletal muscle mass using the resistance measured by BIA (Janssen, Heymsfield, Baumgartner, & Ross, 2000). However, the developed equation had several limitations to apply to elderly Asians. First, the study population included young-aged Caucasians. Age and ethnicity are crucial factors to the determination of resistance in BIA (Chien, Huang, & Wu, 2008; Janssen et al., 2000; Kyle et al., 2004b). Second, "whole body" skeletal muscle mass was measured in previous studies instead of ASM, which is known to be associated with muscle strength, physical function and activity of daily living in elderly people (Baumgartner, 2000; Cruz-Jentoft et al., 2010).

There have been no estimated equations for ASM derived from BIA in comparison with other body composition methods in elderly Asians. We should develop age- and ethnic-specific equation to measure body composition for older Korean adults. We aimed to determine the appropriate BIA equation that predicts

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DXA-measured ASM in older Korean adults and cross-validate the developed equation in another Korean cohort. Furthermore, we investigated the outcome of ASM in terms of muscle strength.

2. Subjects and methods

2.1. Study participants

Two ongoing community-dwelling cohorts, the Ansung cohort and the Korean Longitudinal Study of Healthy Aging (KLoSHA), were included. The Ansung cohort was established for the Korean Health and Genome Study in 2001 to investigate the frequency and determinants of chronic diseases in Korea. Details of the design of this cohort and methods used have been previously described (Shin et al., 2010). In the original Ansung cohort, we included 285 men and 435 women over 65 years of age to generate the estimated equation.

We validated the equation in 198 men and 285 women from the KLoSHA cohort (Lim et al., 2010), who had undergone both BIA and DXA measurement.

Trained staff collected all data using standardized protocols. Informed consent was obtained from all study participants.

2.2. Anthropometric parameters

Height and body weight were measured to the nearest 0.1 cm and 0.1 kg, respectively, in subjects wearing light garments. BMI was computed as weight divided by height squared (kg/m^2).

2.3. Dual energy X-ray absorptiometry

ASM was measured by DXA (Lunar Corporation, Madison, WI) and calculated as the sum of the mass of lean soft tissue in both arms and legs. The coefficient of variation for our device during measurement on a standard phantom was less than 3%

2.4. Bioelectrical impedance analysis

Bioelectrical resistance was measured using multi-frequency BIA (Inbody 3.0, Biospace Co., Korea) with an operating frequency of 250 kHz. The subjects were in standing position with their arms slightly abducted from the trunk and the legs slightly separated for 5–10 min. The participants were instructed to grasp the handles of the analyzer, thereby providing contact with a total of eight electrodes (two for each foot and each hand). When the measurements stabilized, the analyzer displayed resistance directly and immediately. We used the average resistance from both arms and both legs (R), which was calculated as '(right arm + left arm + right leg + left leg)/4.' From the resistance measured by BIA, we used the calculation of index height^2/resistance (Ht^2/R) (Janssen et al., 2000). It has been known that Ht^2/R index is positively related with skeletal muscle mass (Kyle et al., 2004a).

2.5. Leg muscle strength

The isokinetic strength of the knee extensor muscles was measured using an isokinetic device at an angular velocity of 60°/s (Biodex Medical Systems, Shirley, NY). Subjects were asked to perform two sets of five repetitions, with a 30-s rest between sets, by exerting maximum pressure on the arm of the isokinetic device through the entire range of movement. The concentric peak torque values (Nm) obtained from five torque-angle curves of each set were used to evaluate the extension muscle strengths of the knee joints. Mean peak torque of the right and left knee extensor muscle was used in the analysis.

2.6. Statistical analyses

Data were presented as the mean ± standard deviation (SD) or n (%). The difference between two groups was analyzed by an independent t-test in each cohort. Multivariable linear regression models were applied to estimate the predicted equation for DXA-measured ASM using resistance measured by BIA. The agreement of the two methods was assessed by Bland–Altman analysis (Bland & Altman, 1986). The Pearson's correlation analyses between leg muscle strength and DXA-measured or BIA-estimated ASM were used. All data were analyzed using SPSS for Windows (Version 16.0; SPSS Inc.; Chicago, IL, USA). p-values less than 0.05 were considered significant.

3. Results

Table 1 shows the descriptive characteristics of the study subjects in the two cohorts. Mean age was greater in the Ansung cohort than in the KLoSHA cohort. In men, both BMI and ASM were greater in the KLoSHA cohort than in Ansung cohort. However, women in the KLoSHA cohort had a similar BMI but higher ASM than those in the Ansung cohort. In line with ASM, height^2/resistance (Ht^2/R) was higher in the KLoSHA cohort than in the Ansung cohort in both genders.

We developed a prediction equation in the Ansung cohort. Multiple regression analyses for DXA-measured ASM were performed using Ht^2/R determined by BIA, age, gender and weight as independent variables. The generated prediction equation was the following: ASM (kg) = [($Ht^2/R \times 0.104$) + (age $\times -0.050$) + (gender $\times$ 2.954) + (weight $\times$ 0.055)] + 5.663, where Ht is in centimeters; R is in ohms; for gender, men = 1 and women = 0; age is in years; and weight is in kilograms. The r^2 and standard estimate of errors (SEE) of the regression model were 0.88 and 1.35 kg, respectively. The Ht^2/R index was significantly correlated with lean mass measured by BIA ($r = 0.959$, $p < 0.001$) and explained 82.5% of variances. In our study subjects, ASM was positively related to

Table 1
Descriptive characteristics of study participants.

Variables	Men			Women		
	KLoSHA (n = 198)	Ansung (n = 285)	p	KLoSHA (n = 207)	Ansung (n = 435)	p
Age (years)	70.3 ± 4.8	71.1 ± 3.7	0.030	70.1 ± 3.8	71.0 ± 3.5	0.003
Weight (kg)	66.8 ± 9.8	61.3 ± 9.1	<0.001	57.0 ± 8.1	54.1 ± 8.6	<0.001
Height (cm)	165.3 ± 6.0	163.7 ± 5.6	0.004	151.9 ± 4.9	149.4 ± 5.9	<0.001
BMI (kg/m^2)	24.4 ± 3.2	22.8 ± 3.1	<0.001	24.7 ± 3.2	24.2 ± 3.4	0.103
ASM (kg)	20.5 ± 2.6	19.8 ± 2.7	0.005	13.9 ± 1.8	13.4 ± 1.8	0.001
Resistance (Ω)	231.3 ± 27.5	248.9 ± 31.6	<0.001	274.4 ± 29.3	282.3 ± 32.1	0.003
Ht^2/R	119.8 ± 15.5	109.4 ± 15.2	<0.001	85.1 ± 10.4	80.2 ± 10.8	<0.001

BMI, body mass index; ASM, appendicular skeletal muscle mass; Ht, height; R, resistance.