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original article

Validity of anthropometric equations for the estimation of muscle mass in the elderly

Validade de equações antropométricas para estimar a massa muscular em idosos

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Abstract – The objective of this study was to compare skeletal muscle mass (SMM) in older adults as estimated by dual-energy X-ray absorptiometry (DXA) and three predictive equations. A total of 180 older adults (120 women and 60 men) aged 60 to 81 years were studied. Appendicular SMM was measured by DXA and estimated using predictive equations based on anthropometric measures, age, race, and gender. Agreement between methods was evaluated by the paired t-test, Pearson's correlation coefficient, and dispersion error. The prevalence of sarcopenia estimated with the different methods was compared using the kappa coefficient, sensitivity, and specificity. No difference was observed in mean SMM estimated by the predictive equation of Lee et al. and DXA ($p>0.05$), with a high correlation between methods in men ($r=0.90$; $p<0.001$) and women ($r=0.86$; $p<0.001$). The prevalence of sarcopenia did not differ between methods (DXA = 33.3% vs. equation = 36.1%), with high agreement between methods (kappa = 0.74; $p<0.001$) and high specificity (89%) and sensitivity (86%). The results indicate agreement between DXA and the predictive equation of Lee et al. for estimation of SMM and prevalence of sarcopenia in older adults.

Key words: Anthropometry; Elderly; Muscle mass; Sarcopenia.

Resumo – *O presente estudo objetivou validar equações preditivas para estimar a quantidade de massa muscular esquelética (MME) em idosos. A absorciometria radiológica de dupla energia (DXA) foi adotada como referência, e utilizada para estimar a MME apendicular, cujos valores foram comparados àqueles, obtidos por equações preditivas, que utilizam dados antropométricos, idade, etnia e sexo. A concordância entre os métodos foi verificada pelo teste t pareado, pelo coeficiente de correlação de Pearson e pela medida de dispersão dos erros, enquanto a comparação da prevalência de sarcopenia foi analisada pelo coeficiente de Kappa, pela sensibilidade e especificidade. Foram mensurados 180 idosos (120 mulheres e 60 homens), com idade entre 60 e 81 anos. A quantidade de MME, estimada pela equação preditiva de Lee et al., não diferiu daquela obtida pela DXA ($p>0,05$), e apresentou elevada correlação, tanto em homens ($r=0,90$; $p<0,001$), quanto em mulheres ($r=0,86$; $p<0,001$), com significância estatística. A prevalência de sarcopenia, também, não diferiu entre os métodos (DXA=33,3% e equação=36,1%) e apresentou elevados valores de concordância ($k=0,74$; $p<0,001$), bem como de especificidade (89%) e de sensibilidade (86%). Conclui-se que a equações preditivas, em particular a de Lee et al., são válidas para estimar a quantidade de MME e a prevalência de sarcopenia, em idosos.*

Palavras-chave: *Antropometria; Idosos; Massa muscular; Sarcopenia.*

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INTRODUCTION

Skeletal muscle mass (SMM) is a key component of the assessment of health and nutritional status in older adults.[1,2] SMM constitutes the metabolically active tissue of the human body, and accounts for much of fat-free body mass (FFM). The amount of SMM is associated with physical fitness and fracture prevention.[1,3,4] It is estimated that 15 to 20% o folder adults have deficient levels of SMM; in the presence of reduced muscle strength, this constitutes sarcopenia, which has a prevalence rate of over 50% in persons aged 80 or older.[5]

Estimation of SMM *in vivo* can be accomplished by a variety of methods, such as dual-energy X-ray absorptiometry (DXA), computed tomography (CT), and magnetic resonance imaging (MRI)[6,7]; these three modalities are considered the gold standard for this purpose, but carry a high financial cost that makes their use in population-based studies unfeasible. The brief radiation exposure and little need for patient cooperation[7,8] are appealing advantages of DXA over other methods for assessment of older persons. Despite high agreement between DXA-predicted and MRI-derived estimates of SMM in adults[7] and elderly women,[8] cost is still a concern.

Several authors[7,8] have found that approximately 75% of muscle mass is located in the appendicular region—that is, the upper and lower limbs (arms and legs respectively). Predictive equations have been developed[9-11] for estimation of whole-body skeletal muscle mass on the basis of anthropometric data, which can be collected in a more affordable manner, in an attempt to make SMM calculation easier and enable its use in epidemiological research. However, these equations were developed in other countries, for other populations and age groups, and have yet to be validated for Brazilian older adults.

Gobbo et al.[12] investigated the validity of four such equations[9-11] in adult males (college students) and found only two to be valid as compared with DXA findings. As sarcopenia jeopardizes the health status of older adults, hinders execution of basic, essential activities of daily living, and decreases quality of life; and in light of the population aging process currently underway in Brazil, with consequent increases in the incidence and prevalence of sarcopenia, the present study sought to: a) assess the validity of predictive equations for estimation of SMM in older adults; and b) evaluate the agreement between predictive equation-based estimates of sarcopenia and DXA-predicted measurements of SMM.

METHODS

This cross-sectional study was conducted on a convenience sample of older adults from the capital of a Southern Brazilian state. The criteria for exclusion were age <60 years and/or presence of incapacitating medical conditions (paralysis, stroke, cancer, hypertension, hyper- or hypothyroidism, kidney or liver failure), as determined by telephone interviews with the participants, carried out prior to data collection. A total of 180 subjects

between the ages of 60 and 81 took part in this investigation, a sample size similar to that of other validation studies with the same design.[7,8]

Anthropometric parameters (body mass; height; forearm and mid-upper arm circumference; mid-upper thigh girth; leg circumference) were measured[15] by trained examiners. After collection of anthropometric data, SMM was estimated using the selected equations (Table 1). The choice of predictive equations for analysis was based on a search of the PubMed, SciELO, and LILACS databases. In order to ascertain the validity of these equations, their results were compared to those obtained by DXA (performed on a LUNAR Prodigy DF + 14319 densitometer, GE, Madison, WI, with DPX-L 7.52.002 software), which was chosen as the gold standard for comparison.

Table 1. Predictive equations for estimation of skeletal muscle mass (SMM) proposed by several authors, with correlation coefficient (R^2) and standard error of estimate (SEE) values, stratified by age range and reference standard used for comparison.

No.	Author	Age (years)	Equation	R^2	SEE	Reference standard
01	Martin et al.[10]	55-83	SMM (g) = Ht (0.0553 × CTG²) + (0.0987 × CFG²) + 0.0331 * CCG²) – 2445	0.97	1.53	Dissection
02	Doupe [9]	55-83	SMM (g)= Ht (0.031 × CTG²) + (0.064 × CCG²) + (0.089 × CAG²) – 3006	0.96	1.48	Dissection
03	Lee et al. [11]	20-81	SMM (kg) = Ht_m (0.244 × BM) + (7.8 × Ht) + (6.6 × gender) – (0.098 × age) + (ethnicity – 3.3)	0.86	2.6	MRI

Ht, height (cm); Ht_m, height (m); BM, body mass (kg); CTG, skinfold-corrected mid-upper thigh girth; CFG, skinfold-corrected forearm circumference; CCG, skinfold-corrected mid-calf girth; CAG, skinfold-corrected relaxed arm circumference.
Gender: male=1, female=0; ethnicity: Asian=1.4, African-American=1.2, White=0. MRI, magnetic resonance imaging.

DXA was performed with patients wearing gowns provided by the investigator and free of jewelry, dental appliances, or other metallic objects. The procedure lasted 20 to 30 minutes per subject, and was always performed by the technician in charge of calibrating the densitometer, according to manufacturer instructions.

Total FFM and appendicular FFM (AFFM) values were used for estimation of SMM (kg) according to the Kim et al. equation,[7] which also takes into account age in years and a gender-based score (0 extra points for women and 1 for men):

$$SMM\ (kg) = (1.13 \times AFFM) - (0.02 \times age) + (0.61 \times gender) + 0.97$$

SMM was used to calculate the muscle mass index (MMI), expressed as the SMM divided by height (in meters) squared. Descriptive statistics (means, standard deviations, and frequencies) were used to characterize the sample by gender and age.

The paired *t*-test, Pearson's linear correlation coefficient, and the coefficient of determination (R^2), as well as measures of dispersion, were used to assess the validity of the selected equations. Difference and standard error of estimate (SEE) were analyzed, as well as residual plots.[13] The kappa coefficient, sensitivity, and specificity were used for comparison of the prevalence of sarcopenia.

The classification system proposed by Janssen et al.[14] was used to estimate the prevalence of sarcopenia. The kappa coefficient, sensitivity, and specificity were calculated in the Statistical Package for the Social Sciences (SPSS) 15.0 software environment, with 95% confidence intervals and a level of significance set at 5%.

This study was conducted in accordance with Brazilian National Health Council Resolution no. 196 of 10 October 1996 and was approved by the Universidade Federal de Santa Catarina Human Subject Research Ethics Committee with judgment number 059/05.

RESULTS

The study sample comprised 180 older adults. Most participants (67%) were female. Mean age was 69.3±5.7 years for male subjects and 67.3±5.2 years for female subjects (range, 60–81 years). Mean body fat percentage, as estimated by DXA, was 23.1±5.77% in males and 37.3±6.9% in females. Mean BMI was 28±3.75 kg/m^2 (range, 18.4–39.3 kg/m^2).

In the present study, the predictive equations proposed by Martin et al.[10] and Doupe et al.[9] were found invalid for estimation of SMM, as they produced estimates that were significantly different from DXA measurements, despite acceptable correlation coefficients and standard errors[15] (Table 2).

Table 2. Comparison between DXA-predicted measurement of skeletal muscle mass (SMM) and SMM estimates provided by three different predictive equations.

Method	Mean (kg)	SD (kg)	Δ (kg)	r	R^2	SEE
Males						
DXA[7]	28.0	3.75				
Martin et al.[10]	34.9	6.05	6.9*	0.86	0.74	1.94
Doupe[9]	26.1	4.75	- 1.9*	0.87	0.77	1.83
Lee et al.[11]	27.7	3.07	- 0.3	0.90	0.83	1.62
Females						
DXA[7]	18.6	2.61				
Martin et al.[10]	25.9	5.01	7.3*	0.65	0.51	2.00
Doupe[9]	19.2	3.82	0.6*	0.67	0.52	1.94
Lee et al.[11]	18.3	2.92	- 0.3	0.86	0.80	1.36

*denotes statistically significant difference between estimate and DXA-predicted measurement of SMM ($p<0.05$). Paired *t*-test. SD, standard deviation; Δ, mean difference between estimate and DXA measurement; r, Pearson correlation coefficient; R^2, coefficient of determination; SEE, standard error of estimate; SMM, skeletal muscle mass.

SMM estimates obtained through use of the Lee et al. equation[11] were not statistically different from DXA-predicted SMM measurements. Correlation between this equation and DXA was high both for male subjects ($r=0.90$; $p<0.05$) and for female subjects ($r=0.86$; $p<0.05$). In approximately 75% of participants, the difference in SMM as estimated by the two methods was <2 kg.

Scatter diagrams showed no statistically significant differences between DXA-predicted SMM measurements and SMM estimates calculated with the Lee et al. equation.[11]The mean error of estimate was -0.3 kg (95%CI,

-4.2 to 3.6 kg) in male subjects and -0.3 kg (95%CI, -3.6 to 3.0 kg) in female subjects (Figures 1 and 2).

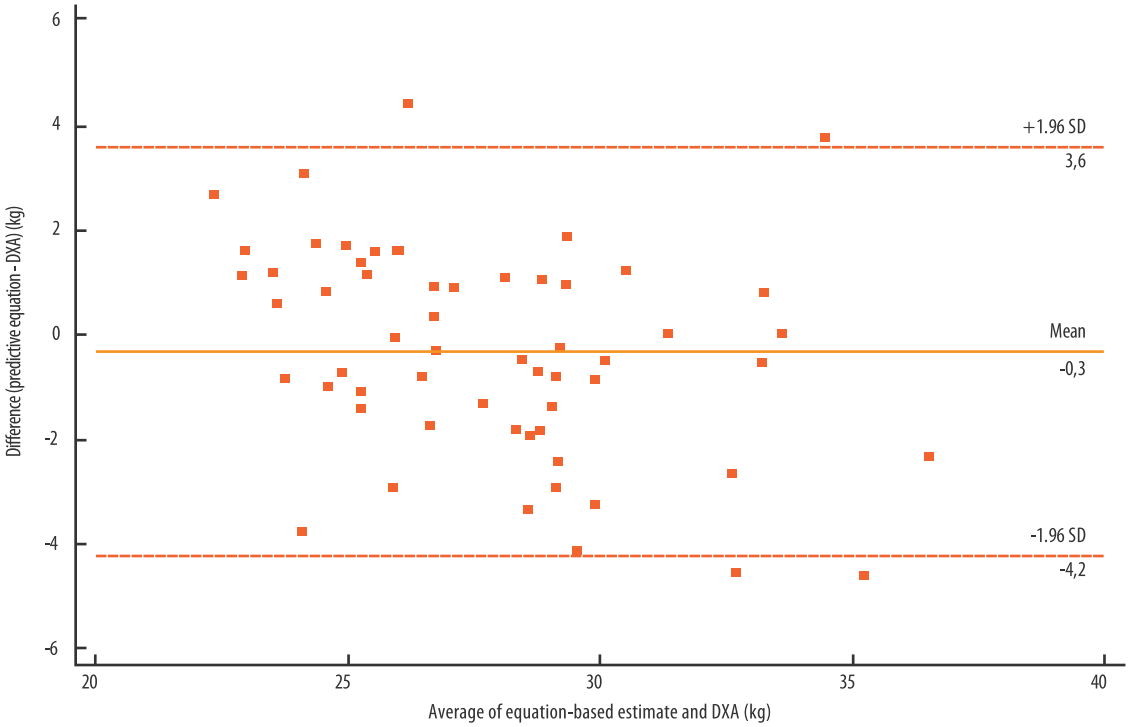

Figure 1. Bland-Altman plot of the differences in skeletal muscle mass (SMM) in kg as estimated by the Lee et al. equation[11] or measured by DXA in male subjects. Dotted lines represent the 95% confidence interval. The solid line represents the mean difference (standard error of the estimate).

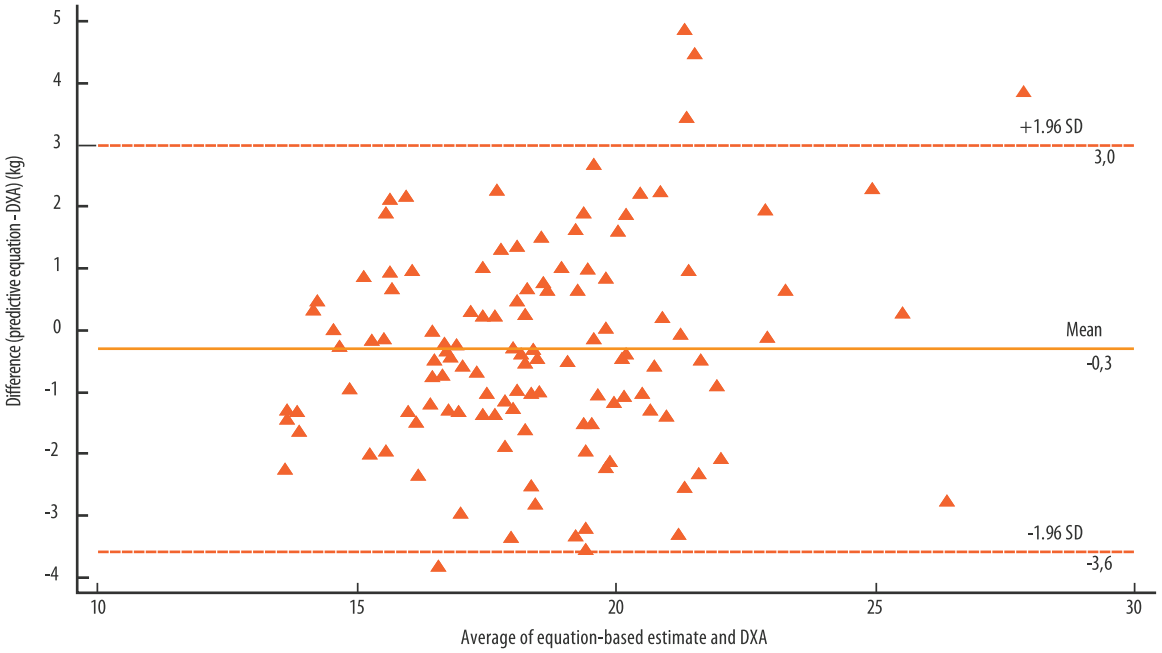

Figure 2. Bland-Altman plot of the differences in skeletal muscle mass (SMM) in kg as estimated by the Lee et al. equation[11] or measured by DXA in female subjects. Dotted lines represent the 95% confidence interval. The solid line represents the mean difference (standard error of the estimate).

Regarding the prevalence of sarcopenia (Table 3), high levels of agreement were found between DXA-predicted measurement and the Lee et al.

Table 3. Prevalence of sarcopenia (%) in the study sample (n=180), as determined by muscle mass index (MMI), stratified by age group and method used for estimation of SMM (DXA or Lee et al. equation[11]) and showing agreement between methods (kappa coefficient) and the sensitivity and specificity, differences, false-positive and false-negative rates of each method.

Age group (years)	60-64	65-69	70-74	≥ 75	Overall
MMI_{DXA} [7] (%)	24.2	30.2	36.5	63.2	33.3
$IMM_{Lee\ (\%)}$	26.2	37.2	40.4	57.9	36.1
Difference (%)	2.0	7.0	3.4	- 5.3	2.8
Sensitivity (%)					86
Specificity (%)					89
False positive rate (%)					8 (4.4%)
False negative rate (%)					13 (7.2%)
Kappa (p)					0.743 (p<0.001)*

*denotes statistically significant agreement (p<0.001).
**sarcopenia was defined as in Janssen et al.[14]
MMI_{DXA}, muscle mass index as measured by DXA; MMI_{Lee}, muscle mass index according to the Lee et al. equation.[11]

equation[11] (kappa 0.743; p<0.001), as well as high sensitivity (86%) and specificity (89%), with no differences in prevalence as estimated by DXA measurement or the Lee et al. equation.[11]

DISCUSSION

The objective of this study was to ascertain the validity of three anthropometry-based predictive equations for estimation of SMM, some taking into account age or ethnicity, developed by Martin et al.,[10] Doupe et al.,[9] and Lee et al.[11] We found the equation developed by Lee et al.[11] to be valid for estimation of SMM in older adults, as compared with DXA-predicted measurement of SMM.

Countless studies have revealed a phenomenon of population aging in developing countries, including Brazil.[16] The prevalence of sarcopenia among older adults is on the rise, as reported by Baumgartner et al.,[5] who found that over 50% of subjects in a sample of New Mexican adults aged 80 or older had sarcopenia, as identified by self-reported measurements.

A review of the scientific literature revealed no population-based studies on the prevalence of sarcopenia in Brazil. This absence can be partially attributed to the lack of low-cost methods for estimation of SMM. A study carried out in a sample of older women revealed reductions in SMM as measured by upper arm muscle area.[18]

In the present study, of the three predictive equations[9-11] available for estimation of SMM in older adults of both genders, only the Lee et al. equation,[11] developed for a sample of adult men and women (aged 20 to 81), provided estimates that were statistically similar to DXA measurements of SMM. These findings corroborate those reported by Gobbo et al.[12] in a study of adult males. Furthermore, the Lee et al. equation[11] had a higher predictive value for SMM and a lower standard error of estimate (SEE) in older adults of both genders as compared with the Martin et al.[10] and Doupe et al. equations.[9]

The variation in SMM estimates provided by the Lee et al. equation[11] was not high. As shown in Figures 1 and 2, 95% of male subjects had esti-

mate errors within a range of -4.2 kg to 3.6 kg (range, 7.8 kg), a variation lower than that reported in a study of adult male college students[12] and in a bioelectrical impedance analysis study of younger and older adults.[19] In women, the difference range was 6.6 kg, superior to that reported by Chen et al. (5.2 kg).[8] However, the authors validated DXA as a method for SMM estimation in older women, with MRI as the gold standard for comparison. Therefore, the Lee et al. equation[11] is valid for estimation of SMM in older adults.

Although the Martin et al.[10] and Doupe et al.[9] equations are cadaver-based, they did not prove valid for estimation of SMM in our study (Table 2), due to significant differences between SMM predicted by these equations and DXA-predicted values. A similar finding was reported by Gobbo et al.,[12] who found that the Martin et al.[10] and Doupe et al.[9] equations tended to overestimate SMM. It should be stressed that the cadaver embalming process may have led to changes in body composition, thus interfering directly with the SMM estimates used to develop these predictive equations. The equations proposed by Martin et al.[10] and Doupe et al.[9] were also invalid for women in our sample (Table 2). This, however, may be explained by the fact that both equations were originally developed using male cadavers as a basis.

The sample-wide prevalence of sarcopenia was 36.1% as estimated by the Lee et al. equation[11] and 33.1% as predicted by DXA,[7] with no statistically significant difference. The use of anthropometric parameters for estimation of SMM has proved valid in several studies.[11,20,21] Calculation of upper arm and thigh muscle area suffices for assessment of changes in SMM; however, a more accurate determination of the extent of sarcopenia requires estimation of whole-body SMM.

The findings reported herein suggest that the Lee et al. equation[11] is valid for estimation of SMM in older adults. Nevertheless, some limitations should be mentioned. Anthropometric estimation of SMM may not provide an accurate portrayal of changes in the muscle tissue. Advancing age is associated with a trend toward adipose infiltration of muscle fibers, which can only be diagnosed accurately in vivo by means of magnetic resonance imaging.[22] The convenience sampling strategy used may have limited estimation of the prevalence of sarcopenia in the study population. Moreover, the sample size was not sufficient for actual stratification of findings by gender and age. However, by presenting these data, we sought to demonstrate the applicability and feasibility of anthropometry-derived estimation of SMM.

Finally, the cutoffs used herein for diagnosis of sarcopenia were obtained from a study carried out in North America, and have yet to be tested in older adults from other locations. Therefore, we suggest that these cutoffs be specifically analyzed in Brazilian older adults so as to determine whether they are associated with reductions in muscle mass and functional disability in this population.

The findings of this study confirm the validity of the Lee et al. equation[11] for estimation of SMM in Brazilian older adults, and also confirm

the applicability of this equation in studies designed to estimate extent of sarcopenia in elderly populations.

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