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Accuracy of a predictive bioelectrical impedance analysis equation for estimating appendicular skeletal muscle mass in a non-Caucasian sample of older people

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ABSTRACT

Objective: To design and validate a predictive BIA equation to estimate ASM in a sample of non-Caucasian older people and to explore the accuracy of two previous single-frequency BIA published equations.
Method: This is a cross-sectional study in 213 physically-independent and apparently healthy older men and women subjects from a central region of Mexico. Dual-energy X-ray absorptiometry, anthropometry, resistance, reactance, and other independent predictive variables were assessed. The total sample was randomized and split into two sub-samples: one group for the development of the predictive single-frequency BIA equation and the other for its validation. The equation was derived by step-wise regression, the goodness of fit was assessed by the highest determination coefficient (R^2) and precision by the lowest root mean square error. In the validation sample, the accuracy of the new and the published BIA equations was tested by pure error. In addition, Bland and Altman analysis tested the bias.
Results: The selected model had a R^2 of 0.91 and a RMSE of 1.01 kg and fulfilled every regression assumption. The predictive variables included were: Ht^2/R, sex, and body weight. The new BIA equation showed a PE close to RMSE of the estimate with no significant bias. The published BIA equations proved to be inaccurate and had significant bias.
Conclusions: This new single-frequency BIA-derived equation was precise, accurate and free of bias. Published BIA equations to estimate ASM should not be used indistinctly in other ethnic groups without validation.

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1. Introduction

Body composition assessment in older people (age > 60 years) is important due to its clinical implications since age-related changes in components of body composition are associated with health risks (Baumgartner, 2000; Gallagher et al., 2000; Hughes et al., 2004). Specifically, the loss of skeletal muscle as an independent variable or as a factor in sarcopenia syndrome has been strongly associated with physical disability, comorbidities and a higher risk of mortality in older people (Arango-Lopera, Arroyo, Gutiérrez-Robledo, & Pérez-Zepeda, 2012; Janssen, Heymsfield, Baumgartner, & Ross, 2000; Janssen, 2004; Szulc, Munoz, Marchand, Chapurlat, & Delmas, 2010; Yamada et al., 2013). Sarcopenia syndrome is currently defined as a stage characterized by low muscle mass plus either low muscle strength or low physical performance (Cruz-Jentoft et al, 2010). For diagnostic purposes, it is necessary to first measure the skeletal muscle component and then translate it into the appendicular skeletal muscle mass index (ASMI) or into the total skeletal muscle mass index (Baumgartner et al., 1998; Bijlsma et al., 2013; Janssen, 2004).

Computed tomography (CT) and magnetic resonance imaging (MRI) are the most accurate methods for measuring skeletal muscle (Lee & Gallagher, 2008; Thomas, 2010; Wells, 2006), but in

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both, developed and developing countries; there are severe limitations on the use of these advanced technologies. Dual-energy X-ray absorptiometry (DXA) is a validated technique for assessing body composition and particularly regional lean tissue (Heymsfield et al., 1990; Lee & Gallagher, 2008; Lohman & Chen, 2005; Visser, Fuerst, & Lang, 1999; Wang et al., 1999). Also, DXA is increasingly accepted as a reference method to design and evaluate single and multi-frequency BIA equations to estimate skeletal muscle (Bosaeus, Wilcox, Rothenberg, & Strauss, 2013; Kim et al., 2014; Kyle, Genton, Hans, & Pichard, 2003; Kyle et al., 2004a; Sergi et al., 2014). However, DXA is not an affordable alternative for many institutions, and so it is mainly used for research purposes and for diagnosis of osteoporosis. BIA in contrast, seems to be an accessible, accurate and precise technique for estimating skeletal muscle mass (Janssen et al., 2000; Pietrobelli, Malavolti, & Battistini, 2009); however, the accuracy of BIA for estimating body composition relies on several static assumptions that limits the application of this technique across age ranges and to the general population of different countries (Bosaeus et al., 2013; Gallagher et al., 1997; Kushner, 1992; Kyle et al., 2004b; Lukaski, 2013; Valencia, Alemán-Mateo, Salazar, & Hernández-Triana, 2003).

In order to improve the accuracy of BIA equations, some age and ethnic group-specific equations have been developed and published as means of estimating ASM (Kim et al., 2014; Kyle et al., 2003; Yoshida et al., 2014). However, when these BIA equations are applied to other populations or in clinical settings, results seem to be biased (Bosaeus et al., 2013; Dehghan & Merchant, 2008). In addition, few predictive BIA equations for skeletal muscle have been developed and validated in non-Caucasian geriatric populations. Therefore, this study aimed to design and validate a predictive BIA equation to estimate ASM in a sample of non-Caucasian older men and women subjects from a region in central Mexico, and to validate two previous published single-frequency BIA equations in our sample of older adults.

2. Materials and methods

2.1. Subjects

This is a cross-sectional study that included 213 apparently healthy older men and women over 60 years of age. The protocol was approved by the Ethical Committee of the Autonomous University of Querétaro and by the Ethical Committee of the Ministry of Health in the state of Querétaro (530/FCN). All subjects lived in the municipality of Querétaro, Mexico, and were recruited from different institutions; they received a complete explanation of the protocol and signed the consent form.

Subjects underwent clinical assessment and body composition assessment by DXA. Blood samples were drawn for thyroid stimulating hormone, glucose, urea, creatinine, creatine phosphokinase, gamma glutamyl transpeptidase. Those with abnormal levels, edema or hypertension were not included, so that only volunteers with normal blood test results, stable body weight in the previous three months, who were free of prescribed medications, physically independent according to Katz's scale (Katz, Ford, Moskowitz, Jackson, & Jaffe, 1963) and without cognitive problems according to Pfeiffer's scale (Pfeiffer, 1975), were included.

2.2. Bone-free lean tissue by DXA

Bone-free lean tissue and other body composition components were assessed by DXA using a Hologic Explorer, QDR-4500W® (Hologic Inc., Waltham, MA). All measurements were done under fasting conditions at the Metabolic Unit of the Faculty of Natural Sciences. Before DXA measurements, subjects were asked to remove all metal accessories and empty their bladder. The analysis of bone-free lean tissue was performed on the DXA-scan according to defined guidelines, with special emphasis on separating the arms and legs from the trunk region (Heymsfield et al., 1990). The cut lines were placed to distinguish arms from chest, legs from trunk and pelvis from trunk. Appendicular skeletal muscle mass is the sum of bone-free lean tissue in the arms and legs. DXA-derived ASM (kg) assumes that this entity represents limb skeletal muscle mass, with a further assumption that limb skeletal muscle mass represents 75% of the total body skeletal muscle mass (Snyder et al., 1975). All DXA measurements were performed by trained personnel, and the equipment was calibrated before use, following the procedure recommended by the supplier. Importantly, for the design of the single-frequency (SF)-BIA equations, ASM was considered as the dependent variable.

2.3. Measurement of predictive or independent variables for predicting ASM

Body weight (kg) was measured using an 813 digital scale (capacity 200 ± 0.01 kg, SECA gmbh & Co, Hamburg, Germany); while standing height (cm) was measured with the Harpenden stadiometer (precision of 810–260 mm ± 0.1 cm; Holtain Ltd. Crosswell, Crymych (Dyfed, UK). Waist, hip, wrist and calf circumferences were also measured, using a metallic Rosscraft anthrotape. All predictive variables were measured according to Lohman's (Lohman, Roche, & Martorell, 1991) procedures, except for waist circumference, which was measured according to WHO standards (WHO, 2008). These measurements were performed in triplicate and mean values were used.

Resistance (R) and reactance (Xc) were measured with a single-frequency BIA, SF-BIA Quantum X (50 kHz), (RJL Systems, Michigan, USA). The equipment was periodically calibrated with a 500 Ω resistor; fluctuations of ±2 Ω were accepted. From height and resistance, the BIA resistance index (Ht^2/R) was constructed. The variables of age (years) and sex (women 0, men 1) were also considered and were coded in order to include them in the predictive models.

2.4. Design of the predictive SF-BIA equations to estimate ASM

First, the total sample was randomized and split into two sub-samples, stratified by sex (1:1). These sub-samples were also randomly assigned to either the development BIA equation group 0 (n = 107; 79 females and 28 males), or the cross-validation BIA equation group 1 (n = 106; 79 females and 27 males); according to Sun & Chumlea (2005) a sample of 100 subjects is enough to derive an accurate equation. Second, a correlation matrix was constructed using several predictive or independent variables; the selection of these variables was based on the biological and statistical relationships with the dependent variable. In this study, the statistical criteria for selection of the independent variables was a r value ≥0.68; value which is considered of high correlation (Taylor, 1990), except for weight (r = 0.578). Step-wise regression procedures were held, in order to derive the best-fitting regression equation. The model with the largest determination coefficient (R^2) and smallest RMSE, was chosen as the best-fit model. In addition, the independent variables included in the final model were tested for significance. Finally, the new and the previous published SF-BIA models were applied to the cross-validation BIA equation group.

2.5. Statistical analysis

A descriptive statistical analysis was performed, and a two sample t-test was used to evaluate differences between men and women and between groups. All results are expressed as means ± standard deviations (SD). As mentioned before, precision was assessed on the

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