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Bioimpedance analysis as an indicator of muscle mass and strength in a group of elderly subjects

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ABSTRACT

Objective: To assess the association between whole-body and calf impedance vectors and muscle mass and strength in a group of elderly individuals.
Material and methods: We carried out a cross-sectional observational study on a sample of 113 elderly people. Anthropometric parameters (weight, height and body circumferences) were determined. Body composition was evaluated using conventional bioimpedance analysis (BIA) and vector bioimpedance analysis (BIVA) (whole-body and calf BIVAs), and muscle strength was determined (manual dynamometry). The results were analyzed using the Student *t*-test or the Mann-Whitney *U*, and the correlations using the Pearson or Spearman test. To compare BIVA results among the subgroups established, the Mahalanobis distance (dM) was calculated and the Hotelling T^2 statistic was used. Statistical significance was set to $p < 0.05$.
Results: Nearly half the sample was overweight. Based on waist circumference, 66.7% of the males and 94.9% of the females showed risk of metabolic complications; calf circumference indicated no risk of disability or skeletal muscle mass depletion. However, BIA and dynamometry detected risk of sarcopenia in more than half the subjects. Whole-body BIVA results agreed with those of the BIA, given that most impedance vectors in both sexes were to the right of major axis of the tolerance ellipses. This shows cell mass depletion. While the whole-body BIVA distinguished the subjects having loss of muscle mass and strength, the specific BIVA (calf) only did so in individuals with muscle mass loss.
Conclusions: Whole-body BIVA detects loss of muscle mass and strength, while calf BIVA only distinguishes subjects having muscle mass loss. The localized BIVA might be an alternative to conventional BIA or whole-body BIVA to assess body composition in the elderly.

1. Introduction

During the last decades, developed societies have undergone demographic aging because of the increase in life expectancy (WHO, 2015). The elderly are vulnerable to nutritional alterations that can negatively affect the development of certain diseases and geriatric syndromes prevalent in this age group, such as sarcopenia, osteoporosis, malnutrition and fragility, among others (Abajo-del-Álamo et al., 2008).

One of the most important biological changes produced with advancing age is the loss of muscle mass, which leads to reduced muscle strength (Vianna et al., 2007; Hairi et al., 2010; Ribeiro and Kehayias, 2014). In 2009 the European Working Group on Sarcopenia in Older People (EWGSOP) defined sarcopenia as a geriatric syndrome characterized by a progressive, generalized loss of skeletal muscle mass and strength, with risk of adverse health results, such as functional limitations, physical disability, problems carrying out basic daily life activities, poor quality of life, and even death (Cruz-Jentoft et al., 2010). This group support using dynamometry to assess muscle strength, and considers bioimpedance analysis monofrequency at 50 kHz, with a tetrapolar electrode configurations (BIA), as a valid alternative to dual X-ray absorptiometry (DXA) for estimating skeletal muscle mass. Both are used to diagnose sarcopenia (Cruz-Jentoft et al., 2010).

Incorporating the handgrip test in nutritional assessment for the

Abbreviations: BIA, bioelectrical impedance analysis; BIVA, bioelectrical impedance vector analysis; CP, calf circumference; EWGSOP, European Working Group on Sarcopenia in Older People; FFM, fat-free mass; FFMI, fat-free mass index; FM, fat mass; FMI, fat mass index; GS, handgrip strength; H, height; R, resistance; SMM, skeletal muscle mass; WC, waist circumference; Xc, reactance; Z, impedance

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elderly may be useful as an early screening tool to link grip strength, functional autonomy, and risk of falls in older adults (Hairi et al., 2010; Sallinen et al., 2010). It is also used as an indicator of fragility (García et al., 2013).

Determining body composition by BIA at 50 kHz uses multiple regression models. The method assumes a percentage of constant hydration and lack of corporal morphologic alterations. Neither assumption is often fulfilled in the elderly (Norman et al., 2007). Several studies have shown that bioimpedance vector analysis (BIVA) is a valid technique for evaluating cell mass and hydration status (Camina-Martín et al., 2014a, 2014b; Camina-Martín et al., 2015) in the elderly because it does not require fulfillment of the assumptions mentioned before. In BIVA impedance vectors are directly interpreted using the BIA-graph (Norman et al., 2007): vector length provides information on tissue hydration, while the length indicates the content of the soft tissue cell mass (Piccoli et al., 1994).

Both conventional (BIA) and vector bioimpedance (BIVA) are normally performed in single-frequency mode (50 kHz) at the level of the entire body with tetrapolar electrodes (hand-foot) (Lukaski, 1991). However, in the geriatric population it is sometimes impossible to perform a whole-body BIA because many individuals present structural alterations, amputations, metal prosthesis, or pacemakers.

Previous studies by our group (Redondo del Río et al., 2015) in a young population demonstrated a link between muscle strength and the electric parameters of the whole-body BIA and specific BIA of the calf. Consequently, the objective of this study was to ascertain whether there was an association between whole-body vectors and the calf and muscle mass and strength in a group of elderly subjects.

2. Material and methods

2.1. Study design and participants

This was a cross-sectional observational study on a group of 113 elderly people living in the community and another group of institutionalized elderly in healthcare centers in Castilla y León (Spain). Excluded were subjects that had prostheses or metal implants, presented an acute condition, had lost > 5% of their weight, presented a body mass index (BMI) of > 34 kg/m^2 or < 17 kg/m^2, or clinical signs of dehydration (skin folds) and/or edemas.

Written informed consent was obtained from all participants. This study was conducted in accordance with the Declaration of Helsinki and all procedures involving human participants were approved by the Clinical Research Ethics Committee (CEIC) East Valladolid Healthcare Area.

Body weight (W; kg) was measured to the nearest 100 g using a SECA scale (Hamburg, Germany); height (H; m) was measured to the nearest 0.1 cm using a SECA stadiometer (Hamburg, Germany); and body circumferences were measured with a flexible, inelastic measuring tape to the nearest 0.1 cm.

Whole body impedance measurements were made using a standard protocol (Lukaski, 1991). A 50-kHz, tetra-polar phase-sensitive BIA (BIA-101; AKERN-Srl, Florence, Italy) introduced a sinusoidal, alternating current of 400 μA to measure resistance (R) and reactance (Xc).

Fat-free mass (FFM) and skeletal muscle mass (SMM) (kg) were estimated with the BIA equations developed by Kyle et al. (2001) and by Janssen et al. (2004). Fat mass (FM; kg) was calculated as W – FFM. Then, FM, FFM, and SMM indices (FFMI, FMI and SMI, respectively) were calculated as FMI (kg/m^2) = FM/H^2; FFMI (kg/m^2) = FFM/H^2; and SMI (kg/m^2) = SMM/H^2. Finally, FMI, FFMI, and SMI were converted to age- and sex-specific standard deviation (SD) scores (Z-scores) in all subjects using the reference body composition data for Caucasians (Schutz et al., 2002; Janssen et al., 2004).

For BIVA data, R and Xc values of all individuals were normalized by subject height (R/H and Xc/H, Ohm/m). The reference bivariate tolerance ellipses (50%, 75%, and 95% of the distribution of the values in general population) for the adult and older men (Piccoli et al., 1995) were used for the qualitative and semiquantitative assessment of body composition and hydration status in each individual.

For the calf bioimpedance, two measuring (ES1 and ES2) and two injecting electrodes (EI1 and EI2) were placed on the lateral side of the right leg. The ES1 electrode was placed at maximum circumference of the calf; ES2 was placed 10 cm distal to ES1. Injecting electrode EI1 was placed 5 cm proximal to ES1, and EI2 was placed 5 cm distal to ES2 (Sawant et al., 2013).

Handgrip strength (GS) was measured using a Jamar Hand Dynamometer following the protocol of the 2009 American Society of Hand Therapists (ASHT) (Mathiowetz et al., 1984). The test was repeated by three attempts with each hand within 30 s and the highest value of the three measurements was recorded.

2.2. Statistical analysis

All data are presented as mean (SD) or median (25th–75th percentiles). The normality of the distribution of the variables was checked by the Kolmogorov Smirnov or the Shapiro-Wilk tests. A *t*-test or Mann-Whitney *U* test was used for pairwise comparisons, and correlation analyses were performed with Pearson or Spearman correlation tests. Vector analyses were performed with BIVA software developed by Piccoli and Pastori (2002). Statistically significant differences between the mean vectors were assessed with the Hotelling's T^2 test for vector analysis, and distance between groups with the Mahalanobis distance. The level of significance was set at $p < 0.05$. Statistical analysis was performed with SPSS® version 19.0 (SPSS, Chicago, IL, USA).

3. Results

The study sample was composed of 113 subjects, 59 (52.2%) females and 54 (47.8%) males, with an average age of 79.8 years (range: 52.3 to 98.0 years). Most subjects (99, 87.6%) lived institutionalized in a geriatric healthcare center, while only 14 elderly individuals (12.4%) lived in the community. Nearly half of the sample were overweight (Table 1), and the BMI of the females was significantly higher [28.4 kg/m^2 (4.6)] than that of the males [26.1 kg/m^2 (3.8)]. The majority of the subjects were at risk of metabolic complications according to waist circumference [males: 98.7 cm (10.4), females: 99.5 cm (12.6)] (Table 1). The calf perimeter value was similar in both sexes [33.6 cm (2.5) in males and 33.5 cm (3.3) in females], and few subjects showed risk of disability and loss of skeletal muscle mass based on this indicator (Table 1).

The BIA-estimated body composition of the females differed significantly from that of the males: females had a higher proportion of body fat and, consequently, a lower proportion of fat-free and skeletal muscle mass. The indices for fat mass, fat-free mass and skeletal muscle mass were also different (Table 2). As for skeletal muscle mass, 53.7% of the males and 52.5% of the females presented criteria for Class I sarcopenia according to the European Sarcopenia Group, while 13% of the males and 16.9% of the females fulfilled criteria for Class II sarcopenia. As expected, the females showed significantly less grip strength than the males [19.3 kg (6.0) vs. 30.0 kg (9.2)]. Based on sarcopenia

Table 1
Sample cataloging according to the anthropometric characteristics.

Sample characteristics		Males (n = 54) n (%)	Females (n = 59) n (%)
BMI	Risk of malnutrition	8 (14.8)	3 (5.1)
	Overweight/obesity	13 (24.1); 10 (18.5)	12 (20.3); 21 (35.6)
WC	Metabolic risk	36 (66.7)	56 (94.9)
CP	Risk of SMM loss	5 (9.3)	10 (16.9)

BMI: body mass index (kg/m^2); CP: calf circumference (cm); SMM: skeletal muscle mass; WC: waist circumference (cm).