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Original article

Skeletal muscle mass in hospitalized elderly patients: Comparison of measurements by single-frequency BIA and DXA

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SUMMARY

Background & aims: There is increasing interest in estimating skeletal muscle mass (SMM) in clinical practice. We aimed to validate a bioelectrical impedance analysis (BIA) prediction equation for SMM, developed in a different healthy elderly population, in a population of hospital patients aged 70 and over, by comparison with dual-energy X-ray absorptiometry (DXA) SMM estimates. Comparison was also made with two other previously published BIA muscle prediction equations.

Methods: Muscle measurements by BIA and DXA were compared in 117 patients with a range of clinical conditions (45 female, 72 male, mean age 75 years).

Results: The BIA equation used yielded an accurate estimate of DXA-derived SMM. Mean (SD) difference was 0.26(1.79) kg (ns). The two other BIA equations over-estimated SMM compared to DXA (both $p < 0.001$), but all equations were highly correlated.

Conclusions: The BIA equation used, developed in a different healthy elderly population, gave an accurate estimate of DXA-derived SMM in a population with various clinical disorders. BIA appears potentially capable to estimate SMM in clinical disorders, but the optimal approach to its use for this purpose requires further investigation.

1. Introduction

Bioelectrical impedance analysis (BIA) is an easily performed and non-invasive way to measure body composition.[1–3] Single frequency BIA (SF-BIA) is commonly used to calculate total body water (TBW) and fat free mass (FFM),[2] and body fat mass (FM) is generally calculated as the difference between body weight (BW) and FFM. There is increasing interest in specifically estimating skeletal muscle mass (SMM), as it may, better than FFM, reflect nutritional status, body protein reserves and function in disease-related malnutrition, cachexia and sarcopenia.[4] Loss of SMM is a process associated with aging as well as with several diseases.[5,6] Furthermore, aging is associated with decreased TBW, bone mass, body cell mass (BCM) and FFM.[1] In healthy elderly, development of sarcopenia may be masked by weight stability.[7] Also, cancer cachexia is defined by an ongoing loss of SMM (with or without loss of FM).[8] Hence, it would be useful to obtain easily-performed BIA measurements of muscle mass in elderly patients.

There are several published prediction equations to estimate SMM by BIA. A SF-BIA equation was developed to predict whole body SMM among healthy Caucasians aged 18–86 years, validated against magnetic resonance imaging (MRI).[9] Another SF-BIA equation used data from healthy volunteers aged 22–94 years to predict appendicular SMM (ASMM), and was validated against appendicular lean soft tissue (ALST) measured by dual-energy X-ray absorptiometry (DXA).[4] However, the use of general BIA prediction equations across different ages, ethnic groups or clinical conditions without prior testing of their validity should be avoided.[2] Thus, it was reported that Kyle equation could not be validated in patients with chronic kidney disease.[10]

DXA is increasingly accepted as reference method to evaluate BIA.[2] DXA yields information on FM, lean soft tissue (LST) and bone mineral content (BMC). The extremities consist primarily of three components: skeleton, fat and muscle; and limb LST has been

Non-standard abbreviations: ALST, appendicular lean soft tissue; ASMM, appendicular skeletal muscle mass; BCM, body cell mass; BIA, bioelectrical impedance analysis; BIS, bioimpedance spectroscopy; BMC, bone mineral content; BW, body weight; DXA, dual-energy X-ray absorptiometry; FFM, fat-free mass; FM, body fat mass; IQR, interquartile range; LST, lean soft tissue; MRI, magnetic resonance imaging; R, resistance; SEE, standard error of estimate; SF-BIA, single frequency bioelectrical impedance analysis; SMI, skeletal muscle mass index; SMM, skeletal muscle mass; TBW, total body water; Xc, reactance.

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shown to represent ASMM.[11] Furthermore, DXA has been validated against MRI to predict total body SMM.[12] A recent study reported the development of prediction equations for bioimpedance spectroscopy (BIS) and BIA to estimate SMM in healthy elderly.[13] These equations were developed from measurements in a population-representative sample of healthy elderly in Sweden.

The aim of this study was to validate the SF-BIA prediction equation for SMM in elderly from the above-mentioned study[13] in an Australian patient population with clinical disorders aged 70 and over, by comparison with DXA estimates of muscle mass. In addition, previously published BIA equations for measurement of muscle mass by Kyle et al.[4] and Janssen et al.[9] were compared with the DXA muscle mass estimates.

2. Patients and methods

At the Body Composition Laboratory, Monash Medical Centre at Clayton, Victoria, Australia, 147 simultaneous measurements of whole-body DXA and wrist-to-ankle single frequency BIA in subjects aged 70 and over were identified from a database. The initial study sample consisted of 81 males and 66 females, age 75 ± 4 years, age range 70–93 years, whose body composition had been studied as part of their admission to the hospital, a large university teaching institution in the southeast of Melbourne, Australia.

The study was approved by the Southern Health Human Research and Ethics Committee.

2.1. Body composition measurements

A total body DXA scan was performed using a narrow fan-beam Lunar Prodigy densitometer (GE Lunar, Madison, WI). This scanner incorporates a constant potential x-ray source at 76 kV and a K-edge filter (cerium) to achieve a congruent beam of stable dual-energy radiation: 38 keV and 70 keV. The total body scanning time was 5–7 min. As the x-ray beam passes through the subject, the beam undergoes attenuation by the tissues. The Lunar Prodigy software version 9 uses a series of complex algorithms to determine the amount of BMC, LST, and FM. The quality control of the DXA scanner using a phantom was performed weekly. Total body composition measurements including automatically defined regions of interest for extremity measurements were performed. Subjects were scanned in the supine position. The DXA examinations were performed by 1 of 3 experienced radiology technologists specially trained for these examinations. The body composition for each subject was calculated automatically by the DXA machine. The results were reported as kilograms for BMC, LST, and FM. The coefficients of variation were 2.0% for the trunk, 2.0% for the legs, and 5.7% for the arms.

Skeletal muscle mass, denoted SMM_{DxA} was calculated from ALST, i.e. the sum of arms LST and legs LST, using the formula of Kim et al.[12] where:

$$SMM_{DXA}(kg) = 1.19 \times ALST(kg) - 1.65$$

Single frequency tetra-polar BIA was performed using an 800 μA (50 kHz) alternating current. Following a minimum 4 h fast, with bladder emptied, patients adopted a supine position with arms spread apart from the body and legs separated. Signal input and output electrodes were placed on the dorsum of the right hand and foot. Recording electrodes were placed at standard positions at wrist and ankle. Total body resistance (R) and reactance (X_c) were measured in ohms using an ImpediMed DF50 single-frequency device (ImpediMed, Ltd., Eight Mile Plains, Queensland, Australia).

Skeletal muscle mass by SF-BIA was calculated using the equation of Tengvall et al.,[13] and denoted $SMM_{TENGVALL}$:

$$SMM_{TENGVALL}(kg) = -24.021 + (0.33 * Ht) + (-0.031 * R) + (0.083 * X_c) + (1.58 * sex) + (0.046 * BW),$$

where Ht = body height (cm); for sex, women = 1 and men = 0; and BW = body weight (kg).

Skeletal muscle mass was also calculated from the Janssen equation (Janssen et al., 2000) and denoted $SMM_{JANSSEN}$:

$$SMM_{JANSSEN}(kg) = \left(Ht^2/R * 0.401\right) + (3.825 * sex) + (-0.071 * age) + 5.102,$$

where Ht is height in centimeters; for sex, men = 1 and women = 0; and age is in years.

Appendicular SMM was calculated from the Kyle et al. equation (Kyle et al., 2003) and denoted $ASMM_{KYLE}$:

$$ASMM_{KYLE}(kg) = -4.211 + \left(Ht^2 / R * 0.267\right) + (0.095 * BW) + (1.909 * sex) + (-0.012 * age) + (0.058 * X_c),$$

where Ht is height in centimeters; for sex, men = 1 and women = 0; and age is in years.

2.2. Statistics

Statistical work was performed in IBM SPSS Statistics, version 19. Descriptive values are presented as mean (SD). A p-value < 0.05 was considered significant. Differences between methods were examined by paired samples t-test and Bland–Altman plots.[14] Differences between groups were examined by independent samples t-test and difference from a test value (zero) by one-sample t-test. Correlations between variables were calculated using linear regression or with Pearson's correlation coefficient. Observations were identified as outliers if their values were outside the interquartile range (IQR) by 1.5 * IQR or more, as defined in the IBM SPSS Statistics software.

2.3. Data quality

Twelve subjects with a BMI below 16 kg/m^2 were excluded, since the model used for estimating skeletal muscle mass from DXA,[12] was not validated below this BMI value.

Data quality of DXA measurements was assessed by examining the difference between DXA weight, i.e. the sum of BMC, LST and FM, and scale weight. If the absolute difference was 3 per cent or more of scale weight, the measurement was excluded. 9/135 DXA scans were thus excluded.

After these exclusions, 126 valid pairs of DXA and BIA measurements (76 males, 50 females) remained and were further analyzed.

3. Results

First, we examined the differences in SMM estimates between DXA and the three BIA equations. The mean difference $SMM_{DxA} - SMM_{TENGVALL}$ was 0.15 (2.36) kg (p for difference 0.477), $SMM_{DxA} - SMM_{JANSSEN}$ was −3.09 (3.33) kg ($p < 0.001$), and $ALST_{DxA} - ASMM_{KYLE}$ was −0.90 (2.08) kg ($p < 0.001$).

Next, outlying observations were identified by inspection of box plots of the differences (data not shown). Basic data on the nine