NUTRITION RESEARCH 32 (2012) 479–485

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Utility of multifrequency bioelectrical impedance compared with dual-energy x-ray absorptiometry for assessment of total and regional body composition varies between men and women

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ARTICLE INFO

Article history:
Received 31 January 2012
Revised 18 May 2012
Accepted 21 May 2012

Keywords:
Multifrequency bioelectrical impedance
Dual-energy x-ray absorptiometry
Body composition
Lean mass
Fat mass
Segmental lean mass

ABSTRACT

Multifrequency bioelectrical impedance analysis of body composition may be an appropriate alternative to dual-energy x-ray absorptiometry. We hypothesized that there would be no significant differences between dual-energy x-ray absorptiometry and either the Biospace (Los Angeles, CA, USA) InBody 520 or 720 multifrequency bioelectrical impedance analysis devices for total lean body mass (LBM), appendicular lean mass (ALM), trunk lean mass (TM), and total fat mass (FM) in 25 men and 25 women (including lean, healthy, and obese individuals according to body mass index), age 18 to 49 years, weight of 73.6 ± 15.4 kg. Both devices overestimated LBM in women (~2.5 kg, $P < .001$) and underestimated ALM in men (~3.0 kg, $P < .05$) and women (~1.0 kg, $P < .05$). The 720 overestimated FM in men (1.6 kg, $P < .05$) and underestimated TM in women (0.6 kg, $P \leq .05$). Regression analyses in men revealed R^2 (0.87-0.91), standard error of the estimate (SEE; 2.3-2.8 kg), and limits of agreement (LOAs; 4.5-5.7 kg) for LBM; R^2 (0.62-0.87), SEE (1.5-2.6 kg), and LOA (3.2-6.0 kg) for ALM; R^2 (0.52-0.71), SEE (2.4-3.0 kg), and LOA (4.6-6.1 kg) for TM; and R^2 (0.87-0.93), SEE (1.9-2.6 kg), and LOA (5.9-6.2 kg) for FM. Regression analyses in women revealed R^2 (0.87-0.88), SEE (1.8-1.9 kg), and LOA (4.1-4.2 kg) for LBM; R^2 (0.78-0.79), SEE (1.4-1.5 kg), and LOA (2.7-2.9 kg) for ALM; R^2 (0.76-0.77), SEE (1.0 kg), and LOA (2.2-2.3 kg) for TM; and R^2 (0.95), SEE (2.2 kg), and LOA (4.3-4.4 kg) for FM. The InBody 520 and 720 are valid estimators of LBM and FM in men and of LBM, ALM, and FM in women; the 720 and 520 are valid estimators of TM in men and women, respectively.

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1. Introduction

More than one-third (34.4%) of Americans are classified as obese, having a body mass index (BMI) of 30 kg/m^2 [1], and obesity trends in the United States have continued to rise over the past 3 decades [2]. Body mass index, however, does not provide an accurate measure of an individual's specific body composition (ie, water, fat, and muscle). The increased prevalence of obesity stresses the need for safe, accurate methods of assessing body composition that are more accessible and economical than the traditional methods, which are largely exclusive to research and clinical settings.

Abbreviations: ALM, appendicular lean mass; BMI, body mass index; BIA, bioelectrical impedance analysis; CV, coefficient of variation; DXA, dual-energy x-ray absorptiometry; FM, total fat mass; ICC, intraclass correlation coefficient; LBM, total lean body mass; LOAs, limits of agreement; MF, multifrequency; ρ_C, Lin correlation coefficient; SEE, standard error of the estimate; TM, trunk lean mass.

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0271-5317/$ – see front matter © 2012 Elsevier Inc. All rights reserved.
doi:10.1016/j.nutres.2012.05.009

Body composition has been traditionally assessed by estimating 2 compartments (lean body mass [LBM] and fat mass [FM]) by hydrostatic weighing, validated by cadaveric analysis [3]. Increasingly, dual-energy x-ray absorptiometry (DXA), which uses a 3-compartment model to account for variation in bone mineral content in addition to LBM and FM, is being used to estimate body composition. Dual-energy x-ray absorptiometry has been validated against a 4-compartment model, which includes body water calculated by isotopic deuterium dilution, across a varied population, and is also considered an acceptable reference method of estimating body composition [4]. However, high cost, risk of radiation exposure with DXA, and/or inaccessibility often limits the use of both DXA and hydrostatic weighing as criterion methods.

More common methods such as bioelectrical impedance analysis (BIA) are available that use proprietary algorithms to obtain body composition estimates. Bioelectrical impedance analysis measures the body's resistance to flow (impedance) of alternating electrical current at a designated frequency between points of contact on the body. Water in body tissue is conducting; therefore, measurement of body impedance can indirectly provide information on the body's tissue content. The prevalence of indirect methods of estimating body composition using BIA is increasing because BIA is easy to operate, noninvasive, and quick; exhibits high interobserver reproducibility; and has been highly correlated with hydrostatic weighing, DXA, and isotopic deuterium dilution techniques in specific populations [5–11].

Multifrequency (MF) BIA devices may have several advantages over single-frequency (SF) BIA devices including recognizing that the human body consists of 5 distinct cylinders (arms, trunk, and legs) with different resistivities over which impedances are measured separately, allowing for segmental water analysis. This allows for regional analyses of lean mass in addition to total LBM, total FM, and total body water. Multifrequency BIA technique also samples over a large range of frequencies to assess extracellular water, eliminating the reliance on empirical data to estimate body composition. Multifrequency BIA may offer a valid method for assessing body composition and an alternative to using radiation-based DXA for assessments of regional body composition. Therefore, we designed a study to test the hypothesis that the Biospace (Los Angeles, CA, USA) InBody 520 and 720 MF-BIA devices are valid and reliable devices for estimating total and regional body composition.

2. Methods and materials

2.1. Participants

Fifty volunteers (25 men, 25 women) aged 18 to 49 years met with the investigators to discuss the informed consent, sign the consent form, and receive instructions to return in the morning (scheduled date) after an 8-hour fast. Volunteers were provided the option to withdraw their participation at any time without consequence. Body composition was assessed on 1 day: twice on the 520, twice on the 720, and once by DXA. Reported body weight is the average of the 4 BIA measurements. Data from all 50 participants were used for analyses. The study was approved by the University of Southern California Institutional Review Board.

2.2. Bioelectrical impedance analysis

Bioelectrical impedance analysis devices measure the change in impedance in body tissues by sending detectable electrical signals through the body. The method is based on the principle that LBM contains virtually all the water and conducting electrolytes in the body, providing a good electrical pathway, whereas fat or fat-containing tissues produce a poor electrical pathway. The Biospace Co Ltd full-body MF-BIA devices estimate segmental composition and use a patented 8-point tactile electrode system established by standing on and gripping electrodes. The BIA devices used in this study were the InBody 720, which uses 6 frequencies (1, 5, 50, 250, 500, and 1000 kHz) and produces 30 impedance values for 5 body segments, and the InBody 520, which uses 3 frequencies (5, 50, and 500 kHz) and produces a total of 15 impedance values for 5 body segments.

2.3. Dual-energy x-ray absorptiometry

Reference values were obtained from a single DXA scan (GE Lunar DPX-iQ 2288; Lunar Radiation Corp, Madison, WI, USA). The DXA unit transmits a low-dose radiation x-ray to obtain tissue density for estimation of lean, fat, and bone mass. Total LBM, appendicular lean mass (ALM; sum of 4 appendages), trunk lean mass (TM), and total FM BIA values were compared with the corresponding DXA values; bone mineral content was added to each lean mass DXA variable for BIA comparison.

2.4. Statistical analyses

Data were analyzed using the Statistical Package for Social Sciences software version 16.0 (SPSS Inc, Chicago, IL, USA) and Microsoft Office Excel 2007 (Los Angeles, CA, USA). All data were normally distributed and are presented as means ± SD, unless otherwise stated. Repeated-measures analysis of variance (ANOVA) with Dunnett post hoc *t* test detected between-method differences in body composition estimates. Dunnett *t* test is appropriate for use when comparing test methods to criterion methods. Lin correlation coefficient (ρ_C) and the associated concordance scale (categories include "fair," "moderate," "substantial," and "almost perfect") assessed between-method concordance; a value of 1 indicates perfect concordance [12]. Linear regression determined between-method association (R^2) and standard error of the estimate (SEE). Bland and Altman [13] analyses tested between-method agreement. Intraclass correlation coefficient (ICC) and coefficient of variation (CV%) analyses determined the reliability of each BIA device. Statistical significance was set at $P = .05$. A power analysis was conducted for detecting differences in total body water (not presented here), which revealed a sample size requirement of 25.

3. Results

3.1. Participants

Participant characteristics and body composition estimates are reported (Table 1). The 50 volunteers include 6 obese men (>25% body fat and a BMI of 30 kg/m^2), 6 obese women (>35% body fat and a BMI of 30 kg/m^2), 3 lean men (<10% body fat),

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