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Original article

Prediction of body composition in anorexia nervosa: Results from a retrospective study

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SUMMARY

Background & aims: The assessment of body composition is crucial in evaluating nutritional status in female subjects with anorexia nervosa (AN) and improving their clinical management. The aim of this retrospective study was to assess the accuracy of selected BIA (bioimpedance analysis) equations for fat-free mass (FFM) in female AN subjects and to formulate a specific equation for these subjects.

Methods: Eighty-two restrictive female AN subjects (age 20.5 ± 3.7 yrs, BMI 15.7 ± 1.7 kg/m^2) were studied. Body composition was determined with dual-energy X-ray absorptiometry (DXA) and estimated by BIA using five different equations. Linear correlation analysis was carried out to evaluate the association of FFM with selected variables. Multiple regression analysis was used to formulate specific equations to predict FFM in AN.

Results: All predictive equations underestimated FFM at the population level with a bias from −5.6 to −11.7%, while the percentage of accurate predictions varied from 12.2% to 35.4%. More interestingly, multiple regression analysis clearly indicates that, in addition to weight, ZI_{100} or RI also emerged as independent predictors of DXA-derived FFM, increasing the prediction power of the equation well above that observed with anthropometric characteristics only.

Conclusions: This study shows that the selected predictive BIA equations considered exhibit an insufficient accuracy at the population and the individual level. Predictive formulas based on body weight plus BIA parameters such as RI and ZI_{100} offer a rather accurate prediction of FFM (with high R squared).

1. Introduction

Anorexia nervosa (AN), which is a psychiatric disorder characterized by both underweight and intense fear of gaining weight or becoming fat [1], is a form of protein-energy malnutrition due to decreased food intake and/or compensatory actions such as vomiting, laxative abuse and increased physical activity [2,3].

Body weight and body mass index (BMI, kg/m^2) are widely used to establish the degree of underweight. However, when malnutrition is severe, body weight is not a reliable method for determining nutritional status [4,5]; for instance, lost body cell mass can be replaced by extracellular fluid [4–6]. Thus, evaluating body composition is crucial for nutritional assessment in AN subjects and improving their clinical management. For this purpose, different non-invasive techniques may be used, such as dual-energy X-ray Absorptiometry (DXA), often considered as a reference method, bioelectrical impedance analysis (BIA) and skinfold thickness measurement.

There is evidence in the literature [7,8] that in young adults DXA shows high levels of accuracy in estimating body composition compared with a four-component model [9]. More specifically, a strong correlation between DXA and Computed Tomography was recently found in adult AN individuals irrespective of the level of hydration [10]. Actually, DXA is not so far routinely used in the clinical assessment of such subjects, as is the case with BIA [11,12]. Few studies have examined the limitations of BIA in AN [11], and there are currently no widely accepted disease-specific equations for estimating body composition in these subjects [12,13]. Previously, Scalfi et al. [14] predicted total body water (TBW) and Bedogni et al. [15] fat-free mass (FFM) with BIA in small groups of AN

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and control women, using deuterium oxide (D_2O) and DXA as reference method, respectively. More recently, Mattar et al. [16] studied underweight AN subjects, comparing measurements of FFM and fat mass (FM) using DXA and five different BIA equations already validated in healthy populations, showing large differences in accuracy.

Based on this background, the aim of our study was to evaluate the accuracy of selected BIA equations used to estimate body composition in AN and to identify significant predictors in order to propose new predictive equations of FFM in AN female subjects.

2. Materials and methods

2.1. Individuals

A group of 82 clinically stable restrictive anorexia nervosa patients (DSM-IV, 1994) attending the outpatient clinic of the Clinical Nutrition Unit, Department of Clinical Medicine and Surgery, Federico II University Hospital, Naples, Italy, was considered in this retrospective study (between October 2009 and December 2014).

All patients underwent routine laboratory, clinical evaluations, BIA and DXA in order to support the reliability of widely used predictive equations for body composition and to promote their use in clinical practice. Subjects or parents, when required, gave informed consent for routine diagnostic evaluations. All measurements were performed with a standardized protocol and carried out by experienced staff, in fasting conditions and early in the morning.

2.2. Anthropometry

Body weight was measured to the nearest 0.1 kg with a platform beam scale and height to the nearest 0.5 cm with a stadiometer (Seca 709 and SECA 220, respectively; Seca, Hamburg, Germany). BMI was calculated as body weight (kg) divided by height squared (cm^2).

2.3. DXA

DXA was performed on the whole body using an Prodigy Primo Lunar, A223040501, General Electric Company, Madison (v13.31 software). No special preparation was required; all participants had their underwear on (no metal accessories worn during measurement). DXA uses an X-ray generating source, with two X-ray beams with different energy levels. FFM (lean mass + bone mineral content) and FM are assessed based on their X-ray attenuation properties.

2.4. Bioelectrical impedance analysis

BIA was performed on the non-dominant side of the body in standard conditions: postabsorptive state, at a room temperature between 22 and 25 °C, with the subject being in the supine position for 10 min after voiding [17]. In single-frequency BIA resistance (R, ohm), reactance (Xc, ohm) and phase angle (PhA, degrees) were measured at 50 kHz (BIA 101 analyzer, Akern, Florence), while in multifrequency BIA impedance (Z) was determined at 5, 50 and 100 kHz (Z_5, Z_{50} and Z_{100}) with a Human Im Plus II analyzer (DS Medica, Milan). Subsequently, resistance index (RI = $height^2/R$, cm^2/ohm) and Z indexes at 5, 50, 100 kHz (ZI = $height^2/Z$, ZI_5, ZI_{50} and ZI_{100}, cm^2/ohm) were calculated. For the measurement, four disposable electrodes were placed as follows: a) two injecting electrodes on the dorsum of hand, proximal to the metacarpal-phalangeal joint line, and on the dorsum of foot, proximal to the metatarsal-phalangeal joint line; b) two sensing electrodes on the mid dorsum of wrist, on the line joining the bony prominences of radius and ulna, and ankle, on a line joining the bony prominences of the medial and lateral malleoli. Both the instruments were regularly checked using resistors and capacitors of known values. BIA was also measured in six individuals on subsequent days: all the differences were within ±2% for R, Xc, and Z at different frequencies, and ±4% for PhA.

Three general BIA equations for predicting FFM were chosen according to appropriate validation in healthy Caucasian subjects and applicable age range.

Deuremberg et al. [18] for females:

$$FFM = -12.44 + 0.34 \times RI + 0.1534 \times height + 0.273 \times weight - 0.127 \times age$$

Kyle et al. [19] for females:

$$FFM = -4.104 + 0.518 \times RI + 0.231 \times weight + 0.130 \times Xc$$

Sun et al. [20] for females:

$$FFM = -9.529 + 0.696 \times RI + 0.168 \times weight + 0.016 \times R$$

The specific equations used to evaluate body composition in anorexia nervosa were:

Scalfi-1 [14]:

$$TBW^* = 0.434 \times weight + 6.326$$

Scalfi-2 [14]:

$$TBW^* = (0.563 \times ZI_{100} + 2.695)$$

Bedogni [15]:

$$FFM = 0.6 \times ZI_{50} + 0.2 \times weight + 3.3$$

(*TBW was converted into FFM assuming a 73% water in FFM).

2.5. Statistical analysis

Results are expressed as mean and standard deviation plus minimum and maximum value.

The accuracy of the predictive equations was calculated both at population and individual level. The mean bias was considered as a measure of accuracy at a population level [21]; a reliable estimate was defined as a mean percentage difference ±5% between BIA and DXA-derived FFM. On the other hand, the percentage of individuals with a BIA-DXA difference within ±5% was considered as a measure of accuracy at an individual level. Values lower than 95% indicated underprediction and values higher than 105% overprediction. Finally, the root mean squared prediction error (RMSE) was used to better assess predicted-measured differences in absolute values (no sign).

Linear correlation analysis was carried out to evaluate the association between body composition (FFM and FM) and selected variables (see below), while multiple regression was used to derive equations to predict FFM in female subjects with anorexia nervosa. In both cases, three different sets of variables were considered:

1) general characteristic of individuals: age, height, weight and BMI;
2) single-frequency BIA: R, Xc, RI and PhA;
3) multifrequency BIA (kHz): Z_5, Z_{50}, Z_{100}, ZI_5, ZI_{50} and ZI_{100}.

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