Clinical Nutrition xxx (2016) 1–8

Contents lists available at ScienceDirect

Clinical Nutrition

journal homepage: http://www.elsevier.com/locate/clnu

Original article

Validation of bioelectrical impedance analysis for estimating limb lean mass in free-living Caucasian elderly people

Marina De Rui [a,*], Nicola Veronese [a], Francesco Bolzetta [a], Linda Berton [a], Sara Carraro [a], Giulia Bano [a], Caterina Trevisan [a], Simona Pizzato [a], Alessandra Coin [a], Egle Perissinotto [b], Enzo Manzato [a,c], Giuseppe Sergi [a]

[a] Department of Medicine – DIMED, Geriatrics Division, University of Padova, Padova, Italy
[b] Department of Cardiac, Thoracic and Vascular Sciences, Biostatistics, Epidemiology and Public Health Unit, University of Padova, Padova, Italy
[c] National Research Council, Aging Branch, Institute of Neuroscience, Padova, Italy

A R T I C L E I N F O

Article history:
Received 30 April 2015
Accepted 8 April 2016

Keywords:
Sarcopenia
Body composition
Prediction equation
Limb lean mass
Older adults

S U M M A R Y

Background & aims: Aging is characterized by a loss of limb lean mass (LLM) that can lead to physical disability and death. Regional bioelectrical impedance analysis (BIA) may be a reliable method for estimating LLM, but no prediction equations are available for elderly Caucasian subjects. The aim of this study was to develop and validate a BIA-based equation for predicting LLM in healthy elderly Caucasians, taking dual X-ray absorptiometry (DXA) as the reference method.
Methods: Using a cross-sectional design, 244 free-living healthy Caucasian subjects (117 men, 179 women) over 60 years of age were enrolled. LLM was measured with DXA (LLM_{DXA}), and the resistance (Rz) and reactance (Xc) of each limb were measured with a regional bioelectrical impedance analyzer. A resistive index (RI) was calculated from stature in meters divided by Rz of each arm. A BIA-based multiple regression equation for predicting the lean mass (LM) of dominant and non-dominant limbs was developed using a double cross-validation technique.
Results: Using the sample as a whole, cross-validation resulted in an equation specific for each limb, as follows, where sex equals 1 for males, and 0 for females: LM (kg) = −0.081 + (0.061*RI) + (0.010*body weight) + (0.299*sex) for the dominant arm; LM (kg) = −0.026 + (0.014*RI) + (0.009*body weight) + (0.352*sex) for the non-dominant arm; LM (kg) = −0.462 + (0.027*RI) + (0.047*body weight) + (0.639*sex) + (0.026*Xc) for the dominant leg; and for the non-dominant leg, LM (kg) = −0.522 + (0.029*RI) + (0.045*body weight) + (0.569*sex) + (0.025*Xc). The DXA-measured and BIA-predicted LLM for each limb did not differ significantly.
Conclusion: Our newly-developed BIA equations seem to provide a valid estimation of LLM in older Caucasian adults.

1. Introduction

Regional body composition is an important aspect to consider when assess older adults because body composition changes occurring with aging particularly affect limb muscle mass and is associated with disability, poor quality of life and death [1]. Besides symmetrical lean mass loss caused by aging or chronic diseases [2], other conditions affecting elderly people as consequences of stroke or bone fractures may affect limbs muscle mass asymmetrically. Quantifying limb muscle mass may therefore enable strategies to be developed to minimize the age-related loss of muscle mass and possibly also to identify and monitor individuals warranting rehabilitation programs.

Dual energy X-ray absorptiometry (DXA) is considered the gold standard method for ascertaining segmental body composition. It is commonly taken as a reference for the purpose of validating other tools that are easier to use [3,4] because the use of DXA is limited by its being costly and not portable, having to be done by trained personnel, and entailing exposure to radiation.

Bioelectrical impedance analysis (BIA) is a portable, rapid, noninvasive and reliable method for estimating body composition

* Corresponding author. Clinica Geriatrica – Ospedale Giustinianeo (2° piano), via Giustiniani 2, 35128 Padova, Italy. Tel.: +39 049 8218492; fax: +39 049 8211218.
E-mail address: marinaderui@gmail.com (M. De Rui).

http://dx.doi.org/10.1016/j.clnu.2016.04.011
0261-5614/

in various clinical settings. So far, it has been used primarily to measure "total body" fluids [5], fat-free mass, fat mass [6] and skeletal muscle mass [7–12].

The availability of segmental bioelectrical impedance analyzers enables measurements of the bioelectrical characteristics of single limbs. A procedure involving the positioning of eight electrodes according to the traditional tetrapolar layout on either side of the body has been used to estimate limb lean mass (LLM) in adults [13], but no equations have become available as yet to estimate LLM in elderly people, whose age-related changes in body composition may violate BIA assumptions regarding body shape and current density distribution [14,15].

Hence the aim of the present study was to investigate whether segmental measurements of BIA parameters can predict limb lean mass in a sample of healthy, free-living Caucasian elderly subjects, and to develop a BIA equation for predicting the lean mass (LM) of limbs in the geriatric population, validating it against DXA.

2. Subjects and methods

2.1. Subjects

This cross-sectional study was conducted at the Geriatrics Division of the University of Padova. Caucasian subjects over 60 years of age were recruited on a voluntary basis among the elderly people attending a twice-weekly mild fitness program at public gyms in Padova.

Their healthy condition was established by trained medical personnel from their clinical history, clinical examination and laboratory tests. Individuals with skeletal abnormalities such as kyphosis or scoliosis that might influence their height measurement, and those with significant cardiovascular or pulmonary diseases, uncontrolled metabolic disease (diabetes, anemia or thyroid disease), electrolyte anomalies, cancer or inflammatory conditions were ruled out. Any use of drugs (corticosteroids, hormones, etc.) that might affect body composition was also a reason for exclusion. The study was designed in accordance with the Helsinki Declaration and approved by the local Ethical Committee. All participants were fully informed about the nature, purpose, procedures and risks of the study, and gave their written informed consent.

Among 308 potentially eligible subjects, 244 met the inclusion/exclusion criteria and entered the study.

2.2. Methods

Each subject underwent all the following measurements on the same day:

- anthropometric measurements: body weight was measured to the nearest 0.1 kg using a standard scale with subjects wearing light clothing and no shoes; barefoot standing height was measured to the nearest 0.1 cm by using a wall-mounted stadiometer; BMI was calculated as weight in kilograms divided by height in meters squared;
- multi-dimensional assessment:
  - functional status was assessed using the Activity of Daily Living (ADL) [16] and Instrumental ADL (IADL) [17] scales;
  - physical performance was assessed with the Short Physical Performance Battery (SPPB) [18], considering gait speed, five timed chair stands, and the tandem test; performance scores ranged from 0 to 12, where higher scores indicated a better lower body function;
  - health status was assessed on the Cumulative Illness Rating Scale (CIRS) [19], which classifies comorbidities among 13 organ systems, grading each condition from 1 (no problems) to 5 (severely incapacitating or life-threatening conditions); the comorbidity index (CIRS-CI) is given by the number of conditions graded as ≥ 3;
- dual energy X-ray absorptiometry (DXA): fat-free mass (FFM), lean mass (LM) and fat mass (FM) were assessed on a whole body scan obtained using a DXA fan-beam densitometer (Hologic QDR Discovery A, Hologic Italy). Subjects in their underwear alone were placed supine in the center of the scanning field with their palms facing downwards, their arms lying away from their body, straight or at a slight angle, their feet neutral, and their face turned upwards with their chin neutral. The scan took about 180 s to complete and the dose of radiation per individual was 0.01 mGy (1.0 mrad). The composition of the four limbs was measured in grams by the DXA software. For the purposes of this study, the boundaries of the regions of interest (ROIs) were defined as follows: for the upper limbs, the ROIs (right and left) were defined by a line bisecting the shoulder joint of the right and left arms; the ROIs (right and left) were defined by a line bisecting the hip joint aligned with the iliac crest and pubis. The scanner was calibrated daily using a standard calibration block supplied by the manufacturer. To our knowledge, no information is available on the precision of the QDR Discovery A for measuring body composition, but for the DXA QDR 4500A (Hologic's earlier model) the root mean square percent coefficients of variation are 1.1 for total mass, 1.97% for FM, and 1.46% for LM [20];
- BIA: the study was done with a phase-sensitive segmental bioelectrical impedance analyzer (BIA 101 Anniversary AKERN/RJL Systems) emitting an alternating sinusoidal electric current of 400 μA at an operating single frequency of 50 kHz. Resistance (Rz) and reactance (Xc) were measured directly and automatically for each body segment, and the values were given in ohms (Ω). The device was calibrated every morning using the standard control circuit supplied by the manufacturer that has a known impedance (Rz = 380 Ω 1% precision, and Xc = 47 Ω 1% precision). BIA was performed with patients lying supine with their limbs placed slightly away from their body, after an overnight fast, and having emptied their bladders. BIA measurements were all taken by the same trained investigator to avoid inter-observer errors. Eight low-impedance, high-sensitivity, pre-gelled electrodes (impedance <80 Ω BIATRODES® Akern Srl) were placed according to the traditional tetrapolar method on either side of the participant's body, as reported by Organ et al. [21], and the Rz and Xc were recorded for the following body segments: arms, legs, trunk, upper body, lower body, whole body, and right and left sides. For the present study, only the Rz and Xc for the limbs were considered. The BIA 101 Anniversary is fitted with a very highly sensitive impedance sensor (coefficient of variation <1% resolution 0.1 Ω) and an active electronically switching lead set multiplexer that reduces the error deriving from repositioning the electrodes over the different anatomical landmarks. The repeatability and accuracy of BIA measurements obtained from each body segment enables very small changes to be recorded within a resolution of 0.1 Ω. The resistive index (RI) of each limb was calculated as the participant's stature squared divided by each segmental Rz value (cm^2/Rz).

2.3. Statistical analysis

All analyses were conducted using IBM SPSS Statistics, version 21 (SPSS Inc., Chicago). The Shapiro–Wilk test showed that the continuous variables (age, height, weight, BMI, DXA and BIA parameters) were normally distributed, so they were analyzed using parametric tests, and the results were expressed as

Please cite this article in press as: De Rui M, et al., Validation of bioelectrical impedance analysis for estimating limb lean mass in free-living Caucasian elderly people, Clinical Nutrition (2016), http://dx.doi.org/10.1016/j.clnu.2016.04.011