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Original article

Accuracy of direct segmental multi-frequency bioimpedance analysis in the assessment of total body and segmental body composition in middle-aged adult population

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SUMMARY

Background & aims: Body composition measurement is a valuable tool for assessing nutritional status and physical fitness in a variety of clinical settings. Although bioimpedance analysis (BIA) can easily assess body composition, its accuracy remains unclear. We examined the accuracy of direct segmental multi-frequency BIA technique (DSM-BIA) in assessing different body composition parameters, using dual energy X-ray absorptiometry (DEXA) as a reference standard.
Methods: A total of 484 middle-aged participants from the Leiden Longevity Study were recruited. Agreements between DSM-BIA and DEXA for total and segmental body composition quantification were assessed using intraclass correlation coefficients and Bland–Altman plots.
Results: Excellent agreements were observed between both techniques in whole body lean mass (ICC female = 0.95, ICC men = 0.96), fat mass (ICC female = 0.97, ICC male = 0.93) and percentage body fat (ICC female = 0.93, ICC male = 0.88) measurements. Similarly, Bland–Altman plots revealed narrow limits of agreements with small biases noted for the whole body lean mass quantification but relatively wider limits for fat mass and percentage body fat quantifications. In segmental lean muscle mass quantification, excellent agreements between methods were demonstrated for the upper limbs (ICC female≥0.91, ICC men≥0.87) and lower limbs (ICC female≥0.83, ICC male≥0.85), with good agreements shown for the trunk measurements (ICC female = 0.73, ICC male = 0.70).
Conclusions: DSM-BIA is a valid tool for the assessments of total body and segmental body composition in the general middle-aged population, particularly for the quantification of body lean mass.

1. Introduction

Body composition assessment is being increasingly recognized as an important tool in the evaluation of nutritional status in a variety of clinical conditions[1–3] and for fitness assessment in both research and clinical settings.[4] Moreover, in the elderly, assessment of age-related alterations in body composition[5] will enable development of strategies to minimize the detrimental impact these changes may have on their wellbeing. Furthermore, evaluation of fat mass distribution has been shown to be valuable in predicting cardiometabolic risk.[6,7]

Dual energy X-ray absorptiometry (DEXA) and bioimpedance analysis (BIA) are two frequently used methods for the quantification of body composition. DEXA estimates of body composition have been widely compared to other techniques for assessing body composition such as hydrostatic weighing, CT and MRI,[8–11] and it is now increasingly being utilized as a validation tool for more novel techniques. BIA offers advantages in terms of its simplicity and portability, thus making it an appealing tool in measuring body composition especially in the elderly and less mobile subjects. It is also relatively inexpensive compared to the other techniques and does not expose subjects to radiation.

Previous validation studies of the accuracy of BIA technique using DEXA as reference standards have shown contradictory results. The discordance between results may be due to methodological

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differences such as the various BIA and DEXA devices used, as well as the heterogeneity in the study populations.[12–15] Of the BIA devices developed over the years, the direct segmental multi-frequency BIA (DSM-BIA) has been shown to be superior in the estimation of body composition.[14,16,17] To our knowledge, the use of DSM-BIA in assessing segmental body composition in addition to total body composition in a large middle-aged general population have not been previously reported. Therefore, the aim of the present study was to examine the accuracy of DSM-BIA in the various body composition assessments in a general middle-aged population, using DEXA as the reference method.

2. Methods

2.1. Study sample

The subjects were participants in the Leiden Longevity Study, where 420 families consisting of long-lived Caucasian siblings together with their offspring and the partners of the offspring were recruited.[18,19] The sample of offspring-partner in the study was representative of middle-aged Dutch population. Four hundred and eighty four of the offspring and their partners in whom body composition was measured by DSM-BIA and DEXA were included in the present study. Both investigations were done on the same day 2 h apart. There were no selection criteria on health or demographic characteristics. Information on medical history was requested from the participants' treating physicians. The Medical Ethical Committee of the Leiden University Medical Centre approved the study, and written informed consent was obtained from all subjects.

2.2. Body composition assessment

2.2.1. Direct segmental multi-frequency bioelectrical impedance analysis (DSM-BIA)

DSM-BIA was performed using the In-Body (720) body composition analyzer. This equipment has previously been shown to have high test-pretest reliability and accuracy.[20] Unlike conventional BIA equipment which often takes only partial measurements and therefore relies upon formulas to estimate whole body composition, the DSM-BIA technique employs the assumption that the human body is composed of 5 interconnecting cylinders and takes direct impedance measurements from the various body compartments. A tetrapolar eight-point tactile electrode system is used, which separately measures impedance of the subject's trunk, arms, and legs at six different frequencies (1 kHz, 5 kHz, 50 kHz, 250 kHz, 500 kHz, 1000 kHz) for each of the body segment. The spectrum of electrical frequencies are used to predict the intracellular water (ICW) and extracellular water (ECW) compartments of the total body water (TBW) in the various body segments. Low-level frequencies (eg, 1–50 kHz) rely on the conductive properties of extracellular fluid, whereas, at high-level frequencies (eg, 250 kHz), the conductive properties of both ICW and ECW are instrumental. LBM was estimated as TBW (ICW + ECW)/0.73. FM was calculated as the difference between total body weight and LBM. The machine gives immediate and extensive quantitative values of various body composition parameters. The test was carried out by trained research nurses. The In-Body (720) body composition analyzer has in-built hands and feet electrodes. Subjects wore normal indoor clothings and advised to stand barefooted in upright position with their feet on the feet electrodes on the machine platform and their arms abducted with hands gripping on to the hands electrodes on the handles. Subjects were not require to fast for the test.

2.2.2. Dual energy X-ray absorptiometry (DEXA)

A total body DEXA scan was performed (Hologic QDR 4500, Hologic Inc., Bedford, USA) in a standard fashion. Measurements were performed by a trained technologist with dual energy X-ray beams at 70 and 140 keV. Single rectilinear scanning mode was used on a 148 × 330 pixel matrix in a 196 × 80 cm window. The differential attenuation of the two energies is used to estimate the bone mineral content and the soft tissue composition. Defined regions on the arms, legs and trunk were drawn automatically by the DEXA software and then adapted manually when necessary. The regions of interest for the arms and legs were defined by cut lines positioned proximally at the coracoid process and superior iliac crest and lower ramus respectively. Subjects wore a standard light cotton shirt to minimize clothing absorption.

2.3. Statistical analysis

To account for the gender-related difference in body composition, data was analyzed separately for male and female. Continuous variables with Gaussian distribution are presented as mean (standard deviation). The paired Student's *t*-test was used to compare differences in body composition measurements between the two methods. Intraclass correlation coefficients were used to assess the relationships between whole body composition measurements and segmental lean mass measurements by DEXA and BIA. Systematic differences between LBM_{DEXA} and LBM_{BIA}, FM_{DEXA} and FM_{BIA} and $\%FM_{DEXA}$ and $\%FM_{BIA}$ were examined by Bland–Altman plots. As there was evidence of proportional bias for the FM and %FM measurements, Pearson's correlation was performed to quantify the bias seen in the Bland–Altman plots. To increase clinical utility, linear regression equations were formulated to correct for BIA estimations in relation to DEXA. A 2-tailed *p*-value of <0.05 was considered significant. All statistical analyses were performed using SPSS for Windows (SPSS Inc, Chicago), version 16.

3. Results

Table 1 shows the baseline clinical characteristics and anthropometric parameters of the study population according to gender. Women were slightly younger than men and had lower prevalence

Table 1
Subjects characteristics and anthropometric parameters according to gender.

	Female (*N* = 242)	Male (*N* = 242)
Age, years	61.2 (6.4)	63.5 (6.5)
Comorbidity (%)	15.9	24.7
Myocardial infarct[a]	0.5	3.4
Stroke[b]	1.5	3.9
Diabetes mellitus[c]	4.1	8.9
Malignancy[d]	9.6	7.0
Chronic obstructive pulmonary disease[e]	2.5	7.0
Rheumatoid arthritis[f]	0.5	0.5
Anthropometric parameter		
Height, m	1.66 (0.06)	1.79 (0.07)
Weight,[g] kg	71.8 (12.3)	84.7 (11.5)
BMI, kg/m^2	26.1 (4.4)	26.5 (3.1)
BSA, m^2	1.81 (0.16)	2.05 (0.16)
Waist-to-hip ratio	0.91 (0.07)	0.97 (0.06)

Values are mean (SD) unless otherwise indicated.
BSA = body surface area.
[a] N = 411.
[b] N = 412.
[c] N = 404.
[d] N = 408.
[e] N = 405.
[f] N = 408.
[g] weight derived from whole body mass measurement from DEXA.