



# Comparison of Body Composition Assessed by Multi-Frequency Segmental Bioelectrical Impedance Analysis and Dual Energy X-Ray Absorptiometry in Hemodialysis Patients

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Received 2018 September 02; Revised 2018 September 05; Accepted 2018 September 06.

## Abstract

**Background:** The assessment of body composition during the course of treatment of hemodialysis patients is crucial for optimal treatment. We intended to assess the diagnostic performance of bioelectrical impedance analysis (BIA), which could be used at the bedside in dialysis wards, and compare it with the results of dual-energy X-ray absorptiometry (DEXA).

**Methods:** In a cross-sectional study, 43 patients with end-stage renal disease (ESRD) after hemodialysis sessions underwent direct segmental multi-frequency BIA. Volume status and body composition indices with eight electrodes connected to four limbs were measured at 1, 5, 50, 250, 500, and 1000 kHz frequencies. Then, the patients were sent to the nuclear ward for the corresponding assessments by DEXA. The results of the two methods were compared by a paired *t*-test and the correlations were assessed using general linear models and regression analyses. For the assessment of agreements, Bald-Altman plots were used.

**Results:** The whole body values for bone, fat, and lean body mass were different between BIA (3.4, 22, and 44.5 kg, respectively) and DEXA (1.5, 28.5, and 40.4 kg, respectively). However, the results were strongly linearly correlated even after adjustment for age and sex ( $r = 0.67$ ,  $P = 0.001$  for bone mass;  $r = 0.93$ ,  $P = 0.001$  for fat mass; and  $r = 0.96$ ,  $P = 0.001$  for lean body mass). The same strong correlation was found for the segmental values.

**Conclusions:** The results of BIA and DEXA are correlated strongly and are interchangeable. As the BIA is more easily available and less expensive, the routine use of BIA at hemodialysis departments is reasonable.

**Keywords:** Dual-Energy X-Ray Absorptiometry (DEXA), Bioelectrical Impedance Analysis (BIA), Hemodialysis, Body Composition, Fat Mass, Bone Mass, Lean Body Mass

## 1. Background

Chronic kidney disease (CKD) is a common health problem with a rising prevalence all over the world (1, 2). Unfortunately, in spite of increasing expenditures (3), the patients have high mortality and morbidity (4), as well as a low quality of life (5). Despite the recent technological development, the survival of ESRD patients treated with hemodialysis remains low, with an expected survival less than that for patients with a solid tumor (6). An important factor to control this problem is improving the nutritional status of these patients (7). Malnutrition has been identified as a major independent risk factor for survival of patients undergoing hemodialysis (8). Many patients are old, malnourished, and have multiple comorbidities. The stan-

dard anthropometric assessment provides a valuable view of the nutritional status of the patients. Several methods are employed for muscle mass assessment including anthropometrics, creatinine kinetics, bioelectric impedance analysis, and dual-energy X-ray absorptiometry. Among these methods, dual-energy X-ray absorptiometry (DEXA) is the most reliable technique for the estimation of bone mass, fat mass, and lean body mass. However, in comparison with DEXA, bioelectrical impedance analysis (BIA) is more convenient, less expensive, and operational at the patient's bedside in hemodialysis centers (9). The question is the accuracy of the measurements by BIA in comparison with the more acceptable methods. This study assessed the association of the measurements of multi-frequency BIA for the estimation of body composition with the results of

DEXA in outpatient hemodialysis patients. The core assessment was extended to the segmental analysis of upper and lower extremities.

## 2. Methods

The study population included outpatients undergoing hemodialysis for four hours thrice a week. They were at least 18 years old with a history of hemodialysis at least for 3 months. Patients with any of the following complications were excluded from the study: Breastfeeding or pregnancy, intra-cardiac defibrillator device, pacemaker, orthopedic joint device, history of myocardial infarction or cerebrovascular accident, lymphedema, deep vein thrombosis, and psychiatric disorders/diseases. BIA (InBody S10) was performed after the second hemodialysis session while the patients were in the supine position with two electrodes placed on each extremity. In the next step, by using six different frequencies (1, 5, 50, 250, 500, and 1000 kHz), 30 segmental resistances were measured in each individual. The following parameters were assessed by BIA: Intracellular water (ICW), extracellular water (ECW), total body water (TBW), proteins, minerals, free fat mass (FFM), skeletal lean mass, skeletal muscle mass (SMM), body cell mass (BCM), and bone mineral content (BMC). Finally, the patients were referred to the department of nuclear medicine for the assessment of body composition by the DEXA method. Table 1 presents a summary of the specifications of the BIA and DEXA methods. Written informed consent was obtained from all the study subjects. The study conforms to the local and international ethical concerns and it was approved by the Ethics Committee of the University. The difference between the values of BIA and DEXA methods was tested by paired t-test, the correlation was studied by the assessment of Pearson's coefficient of correlation, and the adjustment for the interfering co-variables was assessed by the use of general linear models (i.e. ANCOVA). Bland-Altman's plots were depicted for the assessment of agreement between the results of BIA and DEXA. P value equal to 0.05 was considered for significant changes and correlations in SPSS V. 18 software (Chicago, IL).

## 3. Results

A total of 43 patients (26 males; 60.5%) aged 59.9 ± 12.5 years (males: 57.6 ± 12.3 years; females: 63.5 ± 12.4 years) were recruited to the study. Table 2 represents the main bone, fat mass, and muscle mass indices derived from DEXA and BIA. The bone, fat, and muscle indices are significantly different between the two methods. The differences between the bone, fat, and lean body mass indices

of the two methods were  $1.9 \pm 0.5$ ,  $-6.5 \pm 4.3$ , and  $4.1 \pm 3.6$ , respectively (all differences significant;  $P = 0.0001$ ). The bone, fat, and muscle mass measurements by DEXA and BIA were correlated significantly with reasonably high coefficients of correlation (Figure 1). The lean body mass of four limbs by the two methods was significantly correlated (Table 3). The correlation of the bone mineral density derived from DEXA examination and the bone mass by BIA remained significant after adjustment for the effect of age, sex, and weight ( $r = 0.67$ ;  $P = 0.001$ ). The correlations of the fat mass ( $r = 0.93$ ;  $P = 0.001$ ) and the lean body mass ( $r = 0.94$ ;  $P = 0.001$ ) by DEXA and BIA methods were also significant independent of the effect of age, sex, and weight. The two methods had considerable agreements as shown in Figure 2. The equation for conversion of the values of BIA (X) into the values of DEXA (Y) is as follows:

$$Y = aX + b \quad (1)$$

where a and b are respectively 0.30 and 0.44 for bone content, 0.75 and 7.0, for lean body mass, and 0.96 and 7.3 for fat mass (all in kg).

## 4. Discussion

This study reports a strong correlation between the body composition indices of DEXA and BIA in the whole body and segmental analyses. The differences between the results obtained by the two methods were considerable but the values were easily interchangeable after conversion. The reliable assessment of body composition in routine practice can help improve the quality of life and reduce the morbidity and mortality of patients with ESRD (10). The results of the measurement by DEXA are acceptable (11) although DEXA is often unavailable in hemodialysis wards and expose patients to X-ray albeit very low doses (12). BIA can be used to perform regular assessments of nutritional condition at the bedside since the instrument is portable. The cost of the instrument and consequently, the charge of the procedure are considerably lower for BIA than for DEXA (13). A close linear correlation between the results of DEXA and BIA with the possibility of conversion, when needed, reassures the routine use of BIA.

The results concerning the correlation between the whole body and segmental values of lean body mass by the two methods are consistent with the findings of other studies. Furstenberg and Davenport measured the values for right lower and left upper limbs demonstrating a high correlation between the values of the two methods (14). Ling et al. found a perfect correlation between the whole body measurements of DEXA and BIA ( $r = 0.95$ ) (15) while Anderson et al. replicated the results with certain gender differences (i.e.  $r = 0.91$  in men and  $r = 0.88$  in women)

**Table 1.** The Characteristics of Instrumentation and Methods of Assessment of Body Composition

Assessment Method	Specification
<b>Bioelectric impedance analysis instrument</b>	InBody S10 (Tepral, Perafita, Portugal); two electrodes for each extremity (overall 8 electrodes); six different frequencies (1, 5, 50, 250, 500, and 1000 kHz); overall 30 impedance measurements.
<b>Bone densitometer</b>	STRATOS (DMS group, Mauguio, France); dual energy X-ray radiation, a scan length of less than 60 min; an overall absorbed dose of less than three microSiv per examination; measurement of bone mineral density, lean body, and fat mass in the whole body and segmental analyses.

**Table 2.** Body Composition Indices of Participants Measured by the Two DEXA and BIA Methods<sup>a</sup>

	Males	Females	Total
Age, y	57.6 (12.3)	63.5 (12.4)	59.9 (12.5)
Weight, kg	73.2 (16)	66.1 (15.8)	70.4 (16.1)
Bone - based on DEXA, kg	1.6 (0.3)	1.3 (0.2)	1.5 (0.3) <sup>b</sup>
Fat - based on DEXA, kg	27.4 (11.1)	30.3 (13.1)	28.5 (11.9)
Lean weight - based on DEXA, kg	44.2 (6.9)	34.6 (4.9)	40.4 (7.8) <sup>b</sup>
Bone - based on BIA, kg	3.7 (0.6)	2.9 (0.4)	3.4 (0.7) <sup>b, c</sup>
Fat - based on BIA, kg	19.3 (10.2)	26.1 (12.4)	22 (11.5) <sup>c</sup>
Lean weight - based on BIA, kg	49.4 (8.4)	37.1 (6.4)	44.5 (9.7) <sup>b, c</sup>

<sup>a</sup>Values are expressed as means (SD).

<sup>b</sup>Significant differences ( $P < 0.05$ ) between the values of males and females.

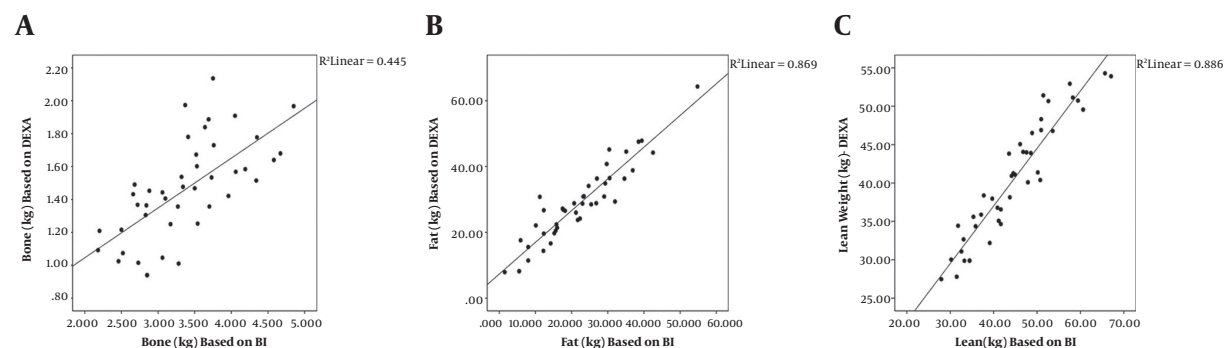
<sup>c</sup>Significant differences ( $P < 0.05$ ) between the values of DEXA and BIA.

**Table 3.** Correlation Between the Segmental Lean Body Mass Values Obtained by the Two Methods

	DEXA	BIA	Mean Difference <sup>a</sup>	Coefficient of Correlation <sup>a</sup>
Right arm	2.68	2.3	-0.4 ( $< 0.001$ )	0.88 ( $< 0.001$ )
Left arm	2.76	2.3	-0.4 ( $< 0.001$ )	0.79 ( $< 0.001$ )
Right leg	7.05	5.7	-1.3 ( $< 0.001$ )	0.89 ( $< 0.001$ )
Left leg	6.91	5.7	-1.2 ( $< 0.001$ )	0.87 ( $< 0.001$ )

Abbreviations: BIA, bioelectrical impedance analysis; DEXA, dual energy X-ray absorptiometry.

<sup>a</sup>Data are differences and coefficients of correlation (Pearson r) and P values are in parentheses.

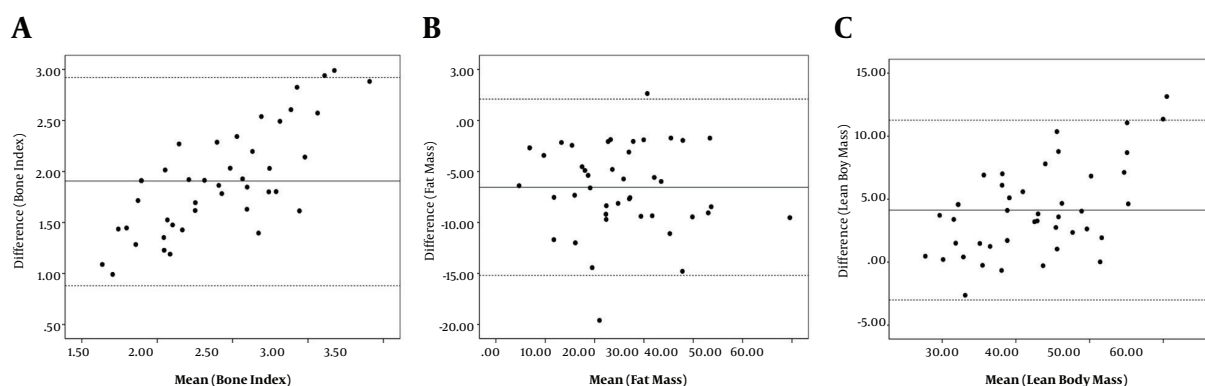


**Figure 1.** Correlation between the body composition indices of by DEXA and BIA. A, B, and C depict the data for bone, fat, and lean body mass.

(16). Notably, the extent of the correlation and correspondingly, the validity of the values in the upper limbs mainly on the left side are weak, probably due to arteriovenous fistula (17). Buckinx et al. found a weak correlation between these two variables. However, one of the limitations of this study was that the hydration status of the persons had not

been determined before BIA running and this factor could influence the results. Table 4 presents a summary of the results and specifications of previous studies.

Several studies have also presented convincing data, considering the correlation of the measurements of fat mass by DEXA and BIA (14-16, 18, 19). There are similar find-



**Figure 2.** Bland-Altman's plot for the assessment of agreement between the measurements by BEXA and BIA methods. Bone mineral content, fat mass, and lean body mass by BIA reasonably correspond to the measurements by DEXA.

**Table 4.** A Summary of the Results of Previous Studies<sup>a</sup>

	Study Year	Sample Size	Fat Mass	Lean Body Mass	Bone Mass	Specification
<b>Furstenberg and Davenport (14)</b>	2011	53 H	0.93	0.95	0.77	Weaker correlation in the upper limbs
<b>Ling et al. (15)</b>	2011	484	0.94			*
<b>Molfina et al. (18)</b>	2012	36 (11 H)	0.87			*
<b>Anderson et al. (16)</b>	2012	50 (25 H)	M = 0.87, F = 0.95			Attention to the gender differences
<b>Kamimura et al. (19)</b>	2003	30	0.91			*
<b>Current study</b>	2015	43 H	0.93	0.96	0.67	Four limbs segmental and whole body

Abbreviation: H, hemodialysis.

<sup>a</sup>Data are coefficients of correlation (i.e. Pearson's r).

\* Indicates only whole body assessment and not segmental.

ings for bone mass (14); however, as it was speculated by Furstenberg, we found that multifrequency BIA overestimates bone mass in hemodialysis patients. The reason behind the increase in bone mass is probably the indirect measurement of bone content by calculations based on the values of normal population that hindered the possibility to extrapolating the calculation algorithm into patients with ESRD suffering acid-base and fluid imbalance (14). Thus, patients are in need of the assessment of bone mineral density by employing the DEXA method periodically.

When the patient is volume overloaded, multifrequency BIA overestimates lean body mass (20). Therefore, measurements should be conducted at a constant hydration status. The advantage of multifrequency BIA is that it can be readily repeated and is noninvasive and inexpensive. Dry weight and target weight for hemodialysis can be calculated by BIA, which would be a great advantage for the quality of hemodialysis and reduction of the complications. The drawback of the procedure is that multifrequency BIA cannot be performed in patients with ICD or pacemaker (21). Malnutrition in patients with ESRD, pa-

tients prone to osteoporosis and more reliable bone mineral assessment density may be yet in need. The camera of DEXA is not readily available at dialysis centers and is expensive. The present study supports the use of multifrequency BIA (InBody S10) in assessing the body composition of hemodialysis patients. Nevertheless, more research is needed for the application of this method in patients with changed body geometry and those with volume imbalance (22). The significance of our study is to provide the segmental measurement of lean body mass in all four limbs by two methods that is unique to the best of our knowledge.

## Footnotes

**Conflict of Interests:** There is no conflict of interests.

**Ethical Considerations:** 9311402002.

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