Comparison of skinfold thicknesses and bioelectrical impedance analysis with dual-energy X-ray absorptiometry for the assessment of body fat in patients on long-term haemodialysis therapy

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Abstract

Background. Body composition assessment in patients with chronic renal failure is of paramount importance since studies have demonstrated the association of protein–energy malnutrition with an increased morbidity and mortality in this population. However, practical and sensible indicators of body compartments are still needed for clinical purposes. Thus, we aimed to evaluate the simple methods of skinfold thicknesses (SKF) and bioelectrical impedance analysis (BIA), using dual-energy X-ray absorptiometry (DEXA) as a reference method, for the assessment of body fat in patients on long-term haemodialysis therapy.

Methods. We studied 30 clinically stable patients (15 men/15 women) undergoing haemodialysis at the Dialysis Unit of the Federal University of São Paulo. Body fat assessment was performed by the SKF, BIA and DEXA methods after a haemodialysis session. Analysis of variance, intra-class correlation coefficient and Bland and Altman plot analysis were used for comparative analysis among the methods.

Results. Body fat estimates by SKF (17.7 ± 7.8 kg) and BIA (18.6 ± 9.2 kg) were not significantly different from those obtained by DEXA (18.2 ± 7.9 kg) considering the whole population. However, the BIA technique worked differently from DEXA when analysed by gender, measuring less fat content in men and higher fat content in women (P < 0.01). No differences were observed for SKF. Strong intra-class correlation coefficients (r) were found between DEXA with SKF (r = 0.94) and BIA (r = 0.91). DEXA showed a relatively good agreement with both SKF [0.47 ± 2.8 (−5.0 to 6.0) kg] and BIA [−0.39 ± 3.3 (−6.9 to 6.1) kg] in all patients according to the Bland and Altman plot analysis. However, considering gender, BIA showed greater mean prediction error of 1.93 ± 2.5 (−3.0 to 6.8) kg for men and −2.71 ± 2.3 (−7.2 to 1.8) kg for women.

Conclusions. The simple and long established method of SKF was preferable over BIA, which showed gender-specific variability in the assessment of body fat in patients undergoing haemodialysis. However, more comparative and longitudinal studies are needed to evaluate the applicability of these practical methods for monitoring body composition in the routine care of patients with chronic renal failure.

Keywords: bioelectrical impedance analysis; body fat; dual-energy X-ray absorptiometry; haemodialysis; skinfold thicknesses

Introduction

Nutritional status affects the survival of patients on long-term haemodialysis therapy. Several studies have demonstrated the association of protein–energy malnutrition with an increased risk of morbidity and mortality in this population [1–4]. On the other hand, the overweight status was revealed to have a positive influence on outcome in maintenance haemodialysis patients in previous studies [5,6]. Thus, the evaluation of body composition in haemodialysis patients is of paramount importance for an adequate intervention that contributes to reduce their high morbidity and mortality.

Practical and sensible indicators of body composition are still needed for clinical purposes. Skinfold thickness (SKF) is a long established method for determining body fat [7]. Although the method has been questioned in condition with altered fat
distribution and because of the inter-observer errors, it is the most simple and inexpensive technique available in the clinical settings and its applicability is possible in a large number of subjects. Bioelectrical impedance analysis (BIA) is another non-invasive method of body composition and it is considered to be highly useful to monitor body compartment changes in various clinical situations [8]. Both methods are based on a two-compartment model that assumes water and mineral content are in the same proportion for all subjects. However, factors related to the process of the disease, such as abnormalities of hydration status and the presence of renal osteodystrophy, may affect the validity of these body composition techniques in patients with chronic renal failure [9]. In fact, Woodrow et al. [10] demonstrated that the magnitude of the errors of both SKF and BIA are greater in patients with chronic renal failure than in healthy subjects.

Dual-energy X-ray absorptiometry (DEXA) measures the three body compartments of fat mass, lean body mass and bone content. Although DEXA requires further investigations so as to be accepted as a gold standard [11], the method has been attributed to be highly precise [12,13] and it is recommended as a valid technique by the clinical practice guidelines for nutrition in chronic renal failure [14].

The present study was conducted in order to evaluate the measurements of body fat obtained by SKF and BIA using DEXA as a reference method in patients on long-term haemodialysis therapy.

**Subjects and methods**

**Patients**

The patients were recruited from the Dialysis Unit of the Federal University of São Paulo—Oswaldo Ramos Foundation. Thirty patients (15 men and 15 women) undergoing haemodialysis therapy thrice weekly were included in this study according to the following criteria: clinically stable adults, with no hospitalization in the month prior to the beginning of the study and without limb amputation. Each subject gave informed consent and this study was approved by the University Ethical Advisory Committee.

**Body composition assessment**

All measurements were performed after a routine haemodialysis session. Patients were weighed with light clothes and without shoes on a platform manual scale balance (Filizola®, São Paulo, Brazil). Measurements of SKF and BIA were executed by the same examiner and DEXA by a laboratory technician.

Skinfold measurements were performed at four sites (biceps, triceps, subscapular and suprailiac) on the opposite side of the vascular access using the Lange® skinfold caliper (Cambridge Intrument, Cambridge, MA, USA). Three sets of measurements were averaged for each site. Body density was calculated using the formula of Durnin and Womersley [7] and the percentage of body fat was then calculated by Siri’s equation [15].

BIA was performed with the patient in supine position ~30 min after the end of the haemodialysis session using a single frequency (50 kHz) tetrapolar technique (BIA 101 Quantum; RJL Systems, Detroit, MI, USA). The electrodes were placed in the standard tetrapolar positions of the non-access side of the patient. A current of 800 µA was introduced at the distal electrodes and the voltage drop was detected by the proximal electrodes. The software Fluids & Nutrition (version 3.0) provided by the manufacturer was used to estimate the body composition.

DEXA was performed using the Hologic QDR model 4500 densitometer (Hologic Inc., Waltham, MA, USA). The body composition was determined by measuring differential attenuation of bone, fat and lean tissue with minimal radiation exposure.

**Biochemical parameters**

Measurements of blood urea nitrogen and serum creatinine were obtained by the blood drawn for routine analysis before the haemodialysis session.

**Statistical analysis**

The results were expressed as mean ± SD. The body fat was measured in kilograms. The measurements obtained by the methods of SKF, BIA and DEXA were compared using analysis of variance. The intra-class correlation coefficient was used to evaluate the strength of the relationships between the methods and the Bland and Altman plot analysis [16] to evaluate the agreement of the SKF and BIA methods with DEXA used as a reference method in this study. The correlation of the inter-method differences with body parameters was obtained by the Pearson correlation coefficient test. The limits of agreement between the methods were defined as the mean difference ± 1.96. Statistical significance was considered when $P < 0.05$.

**Results**

Demographic, clinical and biochemical data of the patients are summarized in Table 1. The patients aged from 24 to 68 years and the vintage of haemodialysis therapy ranged from 8 months to 14 years. Twenty-two patients (73%) presented a body mass

<table>
<thead>
<tr>
<th>Parameter</th>
<th>All patients (n = 30)</th>
<th>Men (n = 15)</th>
<th>Women (n = 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>46.9 ± 11.3</td>
<td>46.1 ± 14.5</td>
<td>47.6 ± 7.3</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>65.3 ± 12.3</td>
<td>67.7 ± 13.8</td>
<td>62.9 ± 10.4</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>165 ± 8.9</td>
<td>170.8 ± 7.3</td>
<td>159.1 ± 6‡</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>23.5 ± 3.4</td>
<td>22.3 ± 3.3</td>
<td>24.7 ± 3.2‡</td>
</tr>
<tr>
<td>Length of haemodialysis (months)</td>
<td>47.2 ± 40.2</td>
<td>38.4 ± 33.6</td>
<td>55.9 ± 45.3</td>
</tr>
<tr>
<td>Blood urea nitrogen (mg/dl)</td>
<td>70.5 ± 15</td>
<td>71.1 ± 13.9</td>
<td>69.4 ± 16.3</td>
</tr>
<tr>
<td>Serum creatinine (mg/dl)</td>
<td>11 ± 3.2</td>
<td>11.7 ± 3.4</td>
<td>10.3 ± 3.2</td>
</tr>
</tbody>
</table>

Mean ± SD.

‡$P < 0.05$ men vs women.
index (BMI) between 18.5 and 25 kg/m², the eight remaining patients (six women and two men) were overweight (BMI > 25 kg/m²). There were no gender-specific differences with regard to age, body weight, length of haemodialysis therapy and biochemical parameters. Height was significantly lower and BMI higher in women. Causes of end-stage renal disease included hypertensive nephrosclerosis (40%), chronic glomerulonephritis (27%), undetermined causes (17%), polycystic kidney disease (6%) and others (10%).

The body fat measurements obtained by the three techniques are reported in Table 2. As can be seen, significantly higher fat values were detected in women by all of the methods (\( P < 0.01 \)). There were no differences in body fat measurements comparing SKF and BIA with the DEXA method in the population as a whole. However, when analysed by gender, BIA exhibited significantly different values of body fat in comparison to DEXA, measuring less fat content in men and higher fat content in women (\( P < 0.01 \)). On the other hand, no significant differences were observed between body fat assessed by the SKF and DEXA methods. As shown in Table 3, strong intra-class correlation coefficients (\( r \)) were found between SKF and BIA with the reference method of DEXA, even considering gender. There was a relatively good agreement between DEXA and both SKF and BIA when the whole population was considered (Table 4). However, we can notice BIA presented a greater error when analysed separately by gender. The difference in body fat between BIA and DEXA correlated significantly with BMI (\( r = 0.48; P < 0.05 \)), but not with body weight. There was no relationship between the body fat difference by SKF and DEXA and the parameters of BMI and body weight. The Bland and Altman plot analysis between the SKF and DEXA methods is illustrated in Figure 1 and between BIA and DEXA in Figure 2.

### Table 2. Body fat measurements by the three methods

<table>
<thead>
<tr>
<th>Methods</th>
<th>Body fat (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All patients ((n = 30))</td>
</tr>
<tr>
<td>SKF</td>
<td>17.7±7.8</td>
</tr>
<tr>
<td>BIA</td>
<td>18.6±9.2</td>
</tr>
<tr>
<td>DEXA</td>
<td>18.2±7.9</td>
</tr>
</tbody>
</table>

<sup>a</sup>\( P < 0.01 \) men vs women.
<sup>b</sup>\( P < 0.01 \) BIA vs DEXA.

### Table 3. Intra-class correlation coefficient (\( r \))

<table>
<thead>
<tr>
<th>Body fat</th>
<th>( r ) (95% confidence interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All patients ((n = 30))</td>
</tr>
<tr>
<td>SKF vs DEXA</td>
<td>0.94 (0.90-0.98)</td>
</tr>
<tr>
<td>BIA vs DEXA</td>
<td>0.91 (0.85-0.97)</td>
</tr>
</tbody>
</table>

### Table 4. Mean differences and limits of agreement for body fat (kg)

<table>
<thead>
<tr>
<th>Methods</th>
<th>Mean difference ± SD (95% limits of agreement)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All patients ((n = 30))</td>
</tr>
<tr>
<td>SKF vs DEXA</td>
<td>-0.47±2.8 ((-6.0 to 5.0))</td>
</tr>
<tr>
<td>BIA vs DEXA</td>
<td>0.39±3.3 ((-6.1 to 6.9))</td>
</tr>
</tbody>
</table>

Fig. 1. Bland and Altman plot analysis to evaluate the agreement between the methods of DEXA and SKF for the assessment of body fat in 30 maintenance haemodialysis patients. The differences of body fat in kilograms are plotted against the mean of body fat obtained by the two methods (open diamonds, men; filled diamonds, women).
Discussion

Assessment of body composition, which is classically divided into fat and fat-free mass, is an important component for providing nutritional care to patients with chronic renal failure. The store of fat, which carries out a potential role for covering the individuals nutritional requirements of energy, is relatively homogeneous in composition. On the other hand, fat-free mass that consists predominantly of water, protein and minerals is very heterogeneous and its measure is affected by abnormalities in fluid and electrolyte distribution commonly observed in the renal population. In the present study, the routine applicable methods of SKF and BIA were analysed for the assessment of body fat in patients undergoing haemodialysis using DEXA as a reference method. We found that the traditional method of SKF showed more similar results in comparison to DEXA than did BIA. Although fat measurements obtained by BIA were comparable to those assessed by DEXA when the entire population was considered, the method worked differently when analysed separately by gender. Few studies in renal disease conducted a comparison analysis of body fat measurements stratified by gender. Stall et al. [17] found in peritoneal dialysis patients that the results for body fat varied significantly by different techniques in men and women. In our study, we observed a tendency for BIA to underestimate fat content in men and overestimate fat in women. Moreover, with the increase in BMI there was a larger error of BIA, as demonstrated by the significant and direct correlation coefficient found between the difference in BIA and DEXA and the parameter of BMI. The variability of the BIA method may be explained in part by factors related to gender differences in body composition and its influence on the principles of the method.

BIA primarily measures total body water and assuming a stable hydration of fat-free mass at 73% the body fat value is then determined. Hence, BIA produces a larger error for measuring adiposity by virtue of dependence on two previous measures (body water and fat-free mass) [8]. In addition, the error might be strengthened by variations in hydration status that occur in patients with chronic renal disease. Indeed, Woodrow et al. [10] reported the variability of the measurements between BIA and DEXA was much greater for body fat than fat-free mass and the error was larger in the chronic renal failure group than in healthy subjects.

In accordance with other studies [10,18,19], we also found similar results of fat content assessed by BIA and SKF when the whole population was analysed. However, the differences became evident when gender was considered. Although there were gender-specific dissimilarities in mean body fat obtained by BIA, the method presented a high correlation coefficient with the reference DEXA as shown in the previous studies in renal patients [17,20]. The correlation of BIA measurements with DEXA maintained high in men as well as in women. In addition, similarly to the SKF method, BIA displayed a relatively good agreement with DEXA according to the Bland and Altman plot analysis in the general population. There were no changes in differences of body fat along the measurements range; however, a systematic error in fat measurement for men and women was confirmed. Thus, our results indicate the importance of conducting the comparative analysis of body composition techniques stratifying by gender.

Finally, regarding comparability of the usefulness between SKF and BIA in routine care of patients undergoing haemodialysis, although some authors have pointed out BIA is preferable over SKF due to the ability of evaluating hydration status and minor
inter-operator error [21,22], BIA seemed not to be appropriate for estimating adiposity in this population. On the basis of our analysis, in which DEXA was used as a reference method, the most simple, inexpensive and long-established method of SKF showed to be more reliable to assess body fat in patients on long-term haemodialysis therapy. Nevertheless, studies are still needed to evaluate these non-invasive and practical methods for monitoring body composition in the clinical routine of patients with chronic renal failure. More comparative and longitudinal studies would be of great importance for the better understanding of the theoretical and practical basis of body composition analysis.

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References


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