EVALUATION OF BODY FAT COMPOSITION IN BRAZILIAN WOMEN BY ANTHROPOMETRY, BIOIMPEDANCE AND DUAL ENERGY X-RAY ABSORPTIOMETRY

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ABSTRACT: This study was designed to evaluate and compare the percentage of body fat (% BF) in women with % BF over 30% by three different methods: skinfolds (SKF), bioelectrical impedance analysis (BIA) and dual energy x-ray absorptiometry (DXA). In addition, the behavior of quantitative variables such as body mass index (BMI) and DXA was evaluated. Twenty-eight volunteers who averaged 27.7 years old, 76.2 kg, 1.63 m tall and with a BMI of 28.5 kg/m² participated in this study. The assessment of body fat by DXA, SKF and BIA gave means of 44.1%, 39.8% and 34.3%, respectively. The BMI data, used to classify obesity, ranged from 22.22 to 37.5 kg/m². Statistical differences were found among the values obtained using the three methods \( P < 0.001 \). It can be inferred that different results may be obtained depending on the technique used for measuring fat percentage; DXA showed the highest sensitivity, followed by SKF and BIA. All techniques provided values strongly associated with BMI; however, some subjects with % BF over 30% were classified as normal weight by BMI.

KEYWORDS: Women; anthropometry; bioelectrical impedance analysis; body fat; obesity.

INTRODUCTION

According to a study done by the Brazilian Ministry of Planning, obesity is of greater concern than malnutrition, because while the latter declined from 9.5% to 2.7% of the population, the number of overweight Brazilian people increased significantly from 23.6% to 49.05% between 1975 and 2009. Other recent data from Brazil indicate that taking into account the total number of obese individuals, i.e., people with body mass index (BMI) over 30, the percentage is 12.4% for men and 16.9% for women (IBGE, 2010). In the United States, 40% of adults are overweight, with a BMI over 25; 32.2% are men, and 35.5% are women (FLEGAL et al., 2010).

In epidemiological studies, the clinical assessment of individuals as being overweight or obese has been commonly performed by determining body composition by the quantification of the main structural components of the human body, dividing it into specific tissues that make up the total body mass. There are several different methods for assessing the body composition in different tissue types, including lean tissues (muscle, bone, and organs) and fat (adipose) tissue (RECH et al., 2006).

Nutritional assessment represents a comprehensive approach to body composition, performed by nutritionists to estimate an individual’s nutritional status and detect their food needs. Several methods can be used to carry out a nutritional assessment; the choice depends on the population, the availability of resources, and the purpose of the study, among other factors (RODRIGUES et al., 2001).

The BMI is the most widely used method for the classification of overweight and obese individuals in adult
populations because it is practical, fast, and uses inexpensive equipment (MCARDLE et al., 2003). Additionally, it serves as an indicator of body density, which correlates with body fat (BF) (NORGAN, 2005). However, BMI is not a measure of fat mass, and therefore, its use for diagnosing BF is questioned (RICARDO; ARAÚJO, 2002).

Skinfolds (SKF) are a largely accepted method for the identification of excess BF (BARBOSA et al., 2001). Moreover, the BF values estimated by this technique are very well associated with the hydrostatic weighing of non-obese individuals (SALEM et al., 2004). In obese population, the large amount of located fat hinders the accurate measurement of SKF (BARBOSA et al., 2001).

Bioimpedance (BIA) is a technique used for the rapid assessment of body composition with relative simplicity (BARBOSA et al., 2001). The technique is based on the fact that tissues with high water and electrolyte content are good conductors of electricity, while tissues with low water concentrations show a high resistance to current flow (MCARDLE et al., 2003).

Dual energy x-ray absorptiometry (DXA) is a widely used technique for measuring body mass and mineral density (MCARDLE et al., 2003), which allows for a fast evaluation and furnishes reliable data. However, DXA is a costly method (RECH et al., 2006; WONG et al., 2002). The data obtained by DXA have been accepted in validation studies and in the development of new techniques for the anthropometric assessment of body composition (RECH et al., 2006).

Different methods for assessing body composition have been compared in healthy individuals (BARBOSA et al., 2001; RODRIGUES et al., 2001), however, more studies of the Brazilian population are still needed, especially in subjects with high body fat, to test and compare the different methods of assessing body composition with the goal of achieving accurate and reliable measurements.

Thus, with the aim of selecting the best method for estimating the body composition of Brazilian women with % BF over 30%, the goal of this study was the evaluation and the comparison of body fat percentage (% BF) in this population, using the methods of SKF, BIA and DXA.

MATERIAL AND METHODS

Participants

Initially, young obese and overweight women were recruited from the students and employees of two universities in Belo Horizonte, Minas Gerais, Brazil. Among fifty registered volunteers, only twenty-eight were invited to participate in the study, because they matched the inclusion criteria, which included the following items: be woman, be between 18 and 40 years old and have a fat percentage over than 30% (Skin fold method). Exclusion criteria included the presence of chronic diseases such as hypertension, diabetes and dyslipidemia, as well as the use of controlled medications. Pregnant and lactating women were also excluded. The volunteers were informed about the potential risks and benefits, and they gave their written consent before starting the study.

This study was approved by the Ethics Committee for Human Research of the Federal University of Minas Gerais (UFMG – Protocol No. 400/05).

Study design

This was a cross-sectional study carried out in Belo Horizonte (Minas Gerais, Brazil) from August to November 2008. The following anthropometric measurements were obtained from the volunteers: height, body mass, BMI and body fat measured by three techniques: SKF, BIA and DXA.

Anthropometry Evaluation

Body mass was determined in a single measurement with the weight distributed evenly between the feet, while subjects were wearing indoor clothing and no shoes. The measurement of height was performed in accordance with the procedures described by Jelliffe (1968).

BMI was calculated with the formula that relates the weight and height squared, and the cutoff points used were those proposed by the WHO (1990).

Measurements of SKF were obtained in triplicate using Lange calipers (Cambridge Scientific Industries, Cambridge, USA) with a uniform pressure of 10 g/mm² in the folds of the triceps, biceps, subscapular and suprailiac in a rotational sequence from the right side of the body. The average values measured at each site were used to calculate body density, according to the formula of Durnin & Womersley (1974). The equation of Siri was used to convert body density into % BF (SIRI, 1961).

Evaluation of body composition by Bioelectrical Impedance

The body resistance and reactance were measured using Biodynamics equipment (8.01 version, 310 model, Biodynamics Corporation, Seattle, USA) with subjects lying in a supine position with arms and legs at 45° from the trunk. The attachment of the electrodes (tetrapolar) and the assessment procedures followed the manufacturer’s guidelines. The measurements of resistance and reactance were converted into % BF using the software coupled to the equipment.

Evaluation of body composition by Dual Energy X-ray Absorptiometry

Body fat was evaluated by DXA (model DPX-IQ, Lunar Radiation Corporation, Madison, USA). During the tests, the participants were not carrying any removable metal objects on their body, such as watches, bracelets, rings, other jewelry or metal accessories. Volunteers were supine on the examination table with the head at the far right,
the feet together and the arms slightly away from the trunk. After scanning the entire body, the equipment provided the values for the components of body composition.

**Statistical analysis**

Descriptive statistics was used to analyze the variables. The results for body fat obtained by SKF, BIA and DXA were analyzed by the Wilcoxon test for the analysis of normality. The identification of the association between the SKF and the BIA scores with DXA was performed by the correlation test, Pearson’s correlation coefficient and Student’s t-test. Box plots were constructed for the analysis of the behavior of quantitative variables such as BMI and DXA (SOKAL; ROHLF, 1995). The statistical programs Statistical Package for the Social Sciences (SPSS, 17.0 version, SPSS Inc., IL, USA) and Minitab (Minitab Inc., PA, USA) were used for processing and analyzing the data.

**RESULTS**

Some characteristics of the individuals who participated in this study are shown in Table 1. Significant differences between the values of % BF were obtained by the three methods. The DXA measurement of two subjects was lower than that of SKF, which could be explained by random fluctuation in the sample.

The data in Table 2 compares the body fat percentages obtained by the three methods and the values of inter-correlation (Pearson’s correlation). The differences among the data were quite significant (p <0.001).

The existence of a correlation between BMI and body fat percentage estimated by the three methods is shown in Table 3.

The comparison between the classification of overweight and eutrophy by BMI and the % BF assessed by DXA is shown in Figure 1.

It can be observed in Figure 1 that some individuals were classified as normal weight by BMI (BMI < 24.99 kg/}

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**Table 1 – Baseline characteristics of the study participants (n = 28).**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>27.74</td>
<td>6.04</td>
<td>18 – 39</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>76.23</td>
<td>10.78</td>
<td>60.50 – 99.70</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.63</td>
<td>0.06</td>
<td>1.54 – 1.75</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>28.49</td>
<td>4.02</td>
<td>22.22 – 37.50</td>
</tr>
<tr>
<td>%BF&lt;sub&gt;DXA&lt;/sub&gt;</td>
<td>44.13</td>
<td>3.71</td>
<td>37.50 – 53.50</td>
</tr>
<tr>
<td>%BF&lt;sub&gt;SKF&lt;/sub&gt;</td>
<td>39.79</td>
<td>3.17</td>
<td>34.00 – 46.10</td>
</tr>
<tr>
<td>%BF&lt;sub&gt;BIA&lt;/sub&gt;</td>
<td>34.40</td>
<td>4.30</td>
<td>26.30 – 43.30</td>
</tr>
</tbody>
</table>

SD = standard deviations; BMI = body mass index; %BF<sub>DXA</sub> = body fat percentage measured by dual energy x-ray absorptiometry; %BF<sub>SKF</sub> = body fat percentage measured by skinfolds; %BF<sub>BIA</sub> = body fat percentage measured by bioelectrical impedance.

**Table 2 – Comparison among body fat percentages obtained by three methods.**

<table>
<thead>
<tr>
<th>Methods</th>
<th>Difference between %BF</th>
<th>r</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>DXA vs. BIA</td>
<td>9.6</td>
<td>0.811</td>
<td>&lt; 0.001’</td>
</tr>
<tr>
<td>DXA vs. SKF</td>
<td>4.7</td>
<td>0.715</td>
<td>&lt; 0.001’</td>
</tr>
<tr>
<td>SKF vs. BIA</td>
<td>4.9</td>
<td>0.682</td>
<td>&lt; 0.001’</td>
</tr>
</tbody>
</table>

%BF = body fat percentage; SD = standard deviations; r = Pearson’s correlation; P = probability values; DXA = dual energy x-ray absorptiometry; BIA = bioelectrical impedance; SKF = skinfolds; ’Methods were significantly different by Student’s t-test (P< 0.001).

**Table 3 – Correlation between BMI<sup>*</sup> and the body fat percentage, estimated by three methods.**

<table>
<thead>
<tr>
<th>Methods</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI vs. %BF&lt;sub&gt;DXA&lt;/sub&gt;</td>
<td>0.851</td>
</tr>
<tr>
<td>BMI vs. %BF&lt;sub&gt;BIA&lt;/sub&gt;</td>
<td>0.847</td>
</tr>
<tr>
<td>BMI vs. %BF&lt;sub&gt;SKF&lt;/sub&gt;</td>
<td>0.861</td>
</tr>
</tbody>
</table>

BMI = body mass index; r = Pearson’s correlation; %BF<sub>DXA</sub> = body fat percentage measured by dual energy x-ray absorptiometry; %BF<sub>SKF</sub> = body fat percentage measured by skinfolds; %BF<sub>BIA</sub> = body fat percentage measured by bioelectrical impedance.
DISCUSSION

It is important to explain that the sample group used in the present study is not a populational one, and therefore, it is not representative of the young women of Belo Horizonte (Minas Gerais, Brazil). However, rigorous control of parameters such as age, nutritional status and menstrual cycle was carried out to standardize the sample.

Health care professionals must perform and interpret body composition assessment to help clients/patients achieve their health-related objectives. Valid and reliable body composition assessment may help the professional to monitor changes in body composition in response to weight loss/gain programs (MCARDLE et al., 2003).

The proportions of water, protein and minerals in the fat-free body, and thus the overall density of the fat-free body (FFBd), vary with age, gender, ethnicity, level of body fatness and physical activity level. Actual variations from the assumed FFBd value may result in a systematic error in estimating %BF. Thus, while the two-component model provides accurate %BF estimates for white males, from whom these assumptions were derived, it may not be suitable for use in population subgroups where the FFBd varies from the assumed value (BOTTARO et al., 2002).

A large number of equations for determining fat percentage from various skinfold measurement sites have been developed. All of these equations are specific for a certain population because they are more accurate when they are used with individuals who are similar in age, sex, fatness and state of training (BOTTARO et al., 2002).

In the present study, significant differences were found among the values for %BF of women as estimated by DXA, BIA and SKF (Table 1). The highest value was obtained by DXA (44.13%), followed by SKF (39.79%) and BIA (34.40%). In fact, these differences were expected due to the heterogeneity of the methods, and they confirm the results of other authors who reported differences in the estimation of %BF obtained by different techniques carried out in various population groups (BARBOSA et al., 2001; BOLANOWSKI; NILSSON, 2001; FRISARD et al., 2005; NEWTON JUNIOR et al., 2006; RECH et al., 2006; SOKAL; ROHLF, 1995; SUN et al., 2005; TOTHILL et al., 1994).

Similar to the present study, Sun et al. (2005) reported that BIA gave rise to lower values than DXA for the body fat of individuals who were classified as obese by the second method.

The high value of % BF by DXA can be explained by the higher sensitivity of this method compared to SKF and BIA (NEWTON JUNIOR et al., 2006), whose lower sensitivities may be associated with factors such as the predictive equations that were developed and validated in caucasian individuals and in developed countries (BARBOSA et al., 2001). Moreover, the fact that the values for % BF obtained by SKF are greater than those obtained by BIA could be associated with the difficulty.
of grasping the fat-fold in women with % BF greater than 30% (BAUMGARTNER et al., 1996).

The SKF prediction equations examined for cross-validation in the study of Barbosa et al. (2001) were the sum of three (Σ3SKF) and seven skinfold measurements (Σ7SKF) developed by Jackson et al. (1980). When these authors compared to % BFdxA, the average % BF obtained from the two SKF equations was significantly lowest. However, McArdle et al. (2003) suggested that the SKF method should not be used to assess the body composition of obese individuals. Similar to this work, results from the present study indicated that the SKF (equation of Durnin & Womersley (1974)) should not be used to assess the body composition of Brazilian women who are with % BF 30. Thus, further studies need to be done to explore how adiposity and fat distribution affect the predictive accuracy of body composition field methods, including the bioimpedance method.

Despite the differences found among these methods for estimating BF, a correlation (p<0.001) between them was observed, as shown in Table 2. The data in this table also indicate that this correlation (r) showed a strong intensity of association, because all r-values were close to or above 0.7.

The investigation of Barbosa et al. (2001) showed some similarity with the results of the present work, with strong correlations reported for obese older women between DXA and BIA (r = 0.85), DXA and SKF when using the equation of Durnin & Womersley (1974) (r = 0.83) and BIA and SKF (r = 0.79).

However, depending on the type of equation used to estimate body fat percentage by SKF and the features of the population, the correlation found between SKF and DXA may not be appropriate, as in the work of Barbosa et al. (2001), who observed a poor correlation between DXA and SKF (calculated by the equation of Jackson et al. (1980)) in a sample of old women.

In the group studied in the present work, a strong correlation between BMI data with the values of % BF as estimated by DXA, BIA and SKF was found, with r-values above 0.8 (Table 3). These results confirm those of other studies published in the literature, which also found a correlation between BMI and DXA in different population groups (r ≥ 0.7) (FLEGAL et al., 2010; FRANKENFIELD et al., 2001).

In a study performed at the Federal University of Santa Catarina (Florianópolis, Brazil), a good correlation (r = 0.79) was reported between % BF measured by DXA and BMI in a group of obese women aged 55 to 77 years old (FLEGAL et al., 2010).

These results indicate that although the BMI is not a specific method for the measurement of BF, it shows a good correlation with % BF, in addition to other advantages reported by Frankenfield et al. (2001), such as low cost and high reproducibility.

According to WHO (1990), the BMI threshold for obesity is 30 and a score of 25% body fat or higher in males and 30% or higher in obese women. Braverman et al. (2010) identified 56% of patients as obese with DXA, while BMI identified 20% as such. Some 37% of patients were misclassified by BMI. Among those classified as obese by DXA, only 34% were classified as obese by BMI. In addition, 5% of patients identified as obese by BMI actually were not obese according to DXA scans. These results confirm those found in the present work.

Comparing BMI criteria with Dr. Bray’s original obesity criteria (defined as BF >25% in men and BF >33% in women), Kennedy et al. (2009) found that approximately 72% of obese females and 54% of obese males were misclassified as normal weight or overweight according to BMI criteria. Their results indicate that the new Bray BF classifications are a better fit to BMI criteria; however, a significant margin of error remains between the two methods. It is evident that age-, gender-, and ethnicity-specific criteria are necessary for more accurate BMI calculations that reflect % BF.

The BMI was used to develop a predictive equation for the percentage of body fat. However, the quadratic relationship between BMI and the percentage of body fat and the random variability in the relationship created a significant error in predicting the percentage of body fat from a regression equation using BMI as the dependent variable. Variability in the difference between the measured and predicted percentages of body fat appeared to be greater in subjects with a BMI below 30 kg/m2 and, by lower coefficients of determination, in the group of subjects with a BMI of at least 30 kg/m2 (FRANKENFIELD et al., 2001).

Corroborating these results, Rech et al. (2006) found some discordance in the prevalence of fat excess in obese women aged between 55 and 77 years old, as assessed by DXA and BMI. Thus, while the sample showed 89.2% of fat excess measured by DXA, this prevalence was reduced to 73.89% when analyzed by BMI.

Significant numbers of people with a BMI below 30 kg/m2 are also obese and thus misclassified by BMI. Percent of body fat and body fat divided by height (m2) are predictable from BMI, but the accuracy of the prediction is lowest when the BMI is below 30 kg/m2. Therefore, measurement of body fat is a more appropriate way to assess obesity in people with a BMI below 30 kg/m2 (FRANKENFIELD et al., 2001).

These results confirm that BMI is not a good quantitative marker of body fat because it may underestimate the percentage of fat and therefore erroneously classify individuals with an excess of body fat (KENNEDY et al., 2009).

**CONCLUSION**

This study showed significant differences between the values of % BF obtained by DXA, SKF and BIA. DXA provided the highest values (44.13%), followed by SKF (39.79%) and BIA (34.40%). DXA was the best method for estimating the body composition of Brazilian women with...
% BF over 30% because of the difficult of grasping the fatfold in this group and we couldn’t control all factors that can affect the results from BIA.

BMI showed a strong association with DXA, SKF and BIA; i.e., the higher the value of % BF found, the higher the BMI value. However, some individuals classified as eutrophic by BMI had % BF values above 30%.


PALAVRAS-CHAVE: Mulheres; antropometria; bioimpedância; gordura corporal; obesidade.

REFERENCES


