Bioelectric impedance overestimates the body fat in overweight and underestimates in Brazilian obese women: a comparation with Segal equation 1

G. D. Pimentel1,2, A. B. Bernhard1, M. R. P. Frezza1, A. E. M. Rinaldi1,3, R. C. Burini1

1Center for Nutritional and Exercise Metabolism (CeMENutri), Botucatu Medical School, Sao Paulo State University (UNESP), Botucatu/SP, Brazil. 2Department of Physiology, Division of Nutrition Physiology – Federal University of Sao Paulo (UNIFESP), Sao Paulo/SP, Brazil. 3Assistant Professor at Uberlândia Federal University. School of Medicine. Minas Gerais/MG, Brazil.

Abstract

Introduction: Overweight and obesity are risk factors to appearance of cardiovascular diseases and anthropometry is important as clinical tool for planning and health policymaking at population level. Thus, aim of this work was to compare the simple body fat percentage (%BF) obtained straight by bioelectric impedance (BIA) to the one obtained by the equation of Segal et al (1988), which uses the BIA resistance value, overweight among adult women.

Methods: This study conducted with 86 adult women (50.5 ± 11.0 years old). Body weight and height were measured and estimated the body mass index (BMI). %BF was assessed by BIA (Biodynamics® model 450) and Segal equation.

Results: %BF derived from BIA (38.0 ± 4.6%) and Segal et al (1988) (38.7 ± 8.1%) were similar (p=0.85). However, when the women were distributed, in two groups based on their BMI, overweight (n=40; BMI= 27.3 ± 1.2 kg/m²) and obesity (n=46; BMI= 36.2 ± 5.1 kg/m²), the two methods presented results significant different (p=0.000). The %BF of overweight women was 34.6±3.6% by BIA and 30.3±2.1% when estimated by Segal equation. In obese women, the %BF was 41.0±3.0% and 46.0±2.6%, respectively.

Conclusion: BIA overestimated %BF in overweight (+14.2%; +3.0 kg) and underestimated in obese (-10.9%; -4.4 kg) women.

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Key words: Body composition. Anthropometric. Body fat. Obesity.

Correspondence: Gustavo Duarte Pimentel Pimentel.
Federal University of Sao Paulo (UNIFESP).
Department of Physiology.
São Paulo
E-Mail: gupimentel@yahoo.com.br

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IMPEDANCIA BIOELECTRICA SOBRESTIMA LA GRASA CORPORAL COM SOBREPESO Y SUBESTIMA EN MUJERES BRASILENAS OBESAS: UNA COMPARACION COM LA ECUACION SEGAL

Resumen

Introducción: El sobrepeso y la obesidad son factores de riesgo para la aparición de enfermedades cardiovasculares y la antropometría es importante como herramienta clínica para la planificación y la formulación de políticas de salud a nivel de la población. Así el objetivo de este trabajo fue comparar el simple porcentaje de grasa corporal (%GC) derivada directamente por medio del análisis de impedancia bioeléctrica (BIA) con el derivada de la Segal et al (1988) la ecuación que utiliza el valor de la resistencia BIA, en las mujeres obesas y con sobrepeso.

Métodos: Este estudio realizó con 86 mujeres adultas (50,5 ± 11,0 años de edad). El peso corporal y la altura se midieron y se calculó el índice de masa corporal (IMC). %GC fue evaluado por BIA (Biodynamics® modelo 450) y Segal ecuación.

Resultados: %GC derivados de BIA (38.0 ± 4.6%) y Segal et al (1988) (38.7 ± 8.1%) fueron similares (p=0.85). No obstante, cuando las mujeres se distribuyeron en dos grupos según su IMC, el sobrepeso (n = 40; IMC = 27.3 ± 1.2 kg/m²) y obesidad (n=46; IMC= 36.2 ± 5.1 kg/m²), los dos métodos que se presentan los resultados de diferencias significativas (p = 0,000). El %GC de las mujeres con sobrepeso fue de 34,6 ± 3,6% por la BIA y el 30,3 ± 2,1% cuando se calcula por la ecuación Segal. En las mujeres obesas, el BF% fue 41,0 ± 3,0% y el 46,0 ± 2,6%, respectivamente.

Conclusión: BIA sobrestimó %GC en sobrepeso (+14,2%; +3,0 kg) y subestimado en obesos (-10,9%; -4,4 kg) las mujeres.

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Introduction

The assessment of the nutritional status of adults is usually carried out by analyzing the body composition, which demands methods assessing the energy reserves and metabolically active tissue mass\(^1\). The most often used methods used in the body composition study establish a quantitative relationship between fat mass and fat-free mass\(^2\).

Nowadays the body mass index (BMI) is the method of evaluation of body weight most used\(^4\). However, this index does not discriminate lean mass and fat mass\(^7\). For this reason, the bioelectric impedance analysis (BIA) has been widely used in the assessment of body composition as it makes the distinction between lean mass and fat mass possible, it is relatively cheap, fast and noninvasive\(^8\). BIA is based on the principle that the body components offer resistance to the passage of the electric current. On the one hand, the lean tissues are highly conductive of electric current due to the quantity of water and electrolytes, that is, they have a low resistance to the passage of electric current. On the other hand, fat, bone, and skin are a means of low conductivity having, therefore, high resistance\(^9\).

In addition, the electric current of BIA does not penetrate the cells, not measuring all the intracellular volume. Nevertheless, the Conference on the Standardization of the Bioelectrical Impedance Analyzes of the American National Health Institute in 1996 considered the method safe and with no side effects or contra-indications\(^10\).

The estimate of body fat percentage (%BF) by BIA has advantages such as the simple and fast measurement because the value is generated on screen or printed, so calculations through formulas are not necessary. However, reliability of the formulas inserted in BIA devices has been receiving criticism\(^11\) once the BIA devices do not bring in their manuals the equation used. Due to this, several equations were developed using only the resistance values got in the BIA with later addition of these to the prediction equations for obtaining the %BF\(^12\).

Associated with the not always consistent results, the aim of this work was to compare the simple %BF obtained straight by BIA to the one obtained by the equation of Segal et al\(^13\), which uses the BIA resistance value, overweight among adult women.

### Methods

**Subjects and Methods**

Descriptive and cross-sectional study was conducted from February to December 2007 in patients screened clinically for lifestyle change program (LSCP) “Mexa-se Pro-Saúde”. The sample consisted of adult and elderly women. The criterion for inclusion was only overweight women, and the one of exclusion was those women with liver, kidney, heart, or peripheral vascular disease, as well as chronic alcoholic women. As a whole, 86 women were assessed, average age 50.5±11.0 years old. All the participants signed the free prior informed consent designed according to the nº 196/96 on “Research involving human beings, from the Health Board of the Ministry of Health” approved by the Ethics Committee of Sao Paulo State University (UNESP-FMB, Brazil).

**Body composition**

In the assessment of body composition, body weight and height were taken followed by BMI calculation\(^14\). All the measurements were checked by trained nutritionists. Measuring of body weight was done in platform anthropometric scale (Filizola\(^a\)) and measuring of body height was done by a portable estadiometer (SECA\(^b\)), according to the norms described by Heyward & Stolarczyk\(^15\). The BMI was used to classify and subdivide the study sample between overweight (BMI = 25-29.9 kg/m\(^2\)) and obese women (BMI ≥ 30 kg/m\(^2\)).

The %BF was obtained by two different ways: straight from BIA (equation not provided by the manufacturer) and by the equation of Segal et al\(^13\) (Table I), calculated from the resistance value (ohm) informed by BIA (Biodynamics® 450 model). The equation of Segal et al\(^13\) was used at this study because the authors have also developed it for women whose BMI >30 kg/m\(^2\) (obese women) or %BF >30%. It is also important to highlight that this equation was developed to individuals of both sexes, with age between 17-62 years old having a %BF of 3-56%. For both classification criteria of %BF, values from 20 to 35% were used as normal\(^16\).

In order to reduce possible changes in water status, the study participants were demanded to follow these steps:

### Table I

<table>
<thead>
<tr>
<th>Calculus</th>
<th>Nutritional status</th>
<th>BMI</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFM (kg)</td>
<td>Euthrofic</td>
<td>&lt; 30</td>
<td>0.000064602 x (Height(^2)) + 0.01397 x (Resistance(_,ohms)) + 0.42087 x (Weight(_kg)) - 0.07012 x (Age(_years)) + 10.43485</td>
</tr>
<tr>
<td>FFM (kg)</td>
<td>Obese</td>
<td>&gt;30</td>
<td>0.00091186 x (Height(^2)) - 0.01466 x (Resistance(_,ohms)) + 0.29990 x (Weight(_kg)) - 0.07012 x (Age(_years)) + 9.37938</td>
</tr>
<tr>
<td>Absolute fat (kg)</td>
<td></td>
<td></td>
<td>(\text{Weight}<em>{\text{kg}} - \text{FFM}</em>{\text{kg}})) / Weight(_kg)</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td></td>
<td></td>
<td>(Absolute fat(<em>{\text{kg}}) x 100) / Weight(</em>{\text{kg}})</td>
</tr>
</tbody>
</table>

BMI: body mass index, FFM: free fat mass.
recommendations: avoid drinking alcoholic beverages as well as caffeine for 24 hours before the test, food fasting for 4 hours before the test, avoid intense exercising for at least 12 hours before the test, and let know about the use of medicine based on diuretics (in this case, the participants were not submitted to the test).

The mensuration occurred with women in supine position, wearing only shorts and no metal accessories, away from any element that could cause electric current leakage, thus not interfering with the measurement of electric voltage. The electrodes were put at the back of the right hand and right foot, with the red and black terminals in the proximal and distal positions, respectively.

**Statistical analysis**

Data normality and the distribution of the variables were tested by using the Kolmogorov-Smirnov test. Next, the variables were expressed by descriptive analysis (mean and standard deviation) and test t (Student) was used to check for any possible differences between the %BF from BIA and from the equation of Segal et al (13). The data analysis was carried out with the aid of software STATISTICA 6.0, considering as significant p<0.05 or corresponding p-value in all tests.

**Results**

The study demonstrated that 46.5% (n=40) of the women were overweight and 53.5% (n=46) were obese. Table II shows the general characteristics of the women included in the study. The average BMI of overweight women was 27.3 ± 1.2 kg/m² and of obese women were 36.2 ± 5.1 kg/m².

No significant difference was found (p=0.85) between the %BF obtained straight by BIA (38.0±4.6%) and the one by the equation of Segal et al (13) (38.7±8.1%) (data not showed). However, while analyzing the women separately according to BMI, a significant difference was found (p=0.000) between the methods, that is, in overweight women the %BF was 34.6 ± 3.6% vs. 30.3 ± 2.1% and in the obese women it was 41.0±3.0% vs. 46.0±2.6%, for BIA and the equation of Segal et al (13), respectively (fig. 1). Thus, the equation of BIA overestimates the %BF in overweight women (+14.2%; +3.0kg) and underestimates it in those who are obese (-10.9%; -4.4kg), when compared to the equation of Segal et al.

**Discussion**

The prevalence of women in this study had already been shown by a several studies. The women in this study had a %BF rate as above the normality (excess fat) (16), for both BIA and equation of Segal et al. Besides, this study also showed that the %BF obtained straight by BIA is not considered a good method when compared to the one obtained by the equation of Segal et al. Also, it was not expected that BIA overestimated the %BF in overweight women and underestimated it in obese women. This way, it is suggested that the %BF obtained by the equation of Segal et al be used as it is considered more reliable and as it has already been mentioned in different papers. The greatest difficulty in using the %BF obtained straight by BIA (Byodinamics model 450®) is the unawareness of the equation inserted in the device.

The reliability of BIA has been receiving some criticism. According to Rodrigues et al in a comparative

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Overweight (n = 40)</th>
<th>Obesity (n = 46)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>53.0 ± 9.5</td>
<td>48.2 ± 11.4</td>
<td>0.083</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>69.5 ± 7.1</td>
<td>89.7 ± 15.0</td>
<td>0.000</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>159.2 ± 7.2</td>
<td>157.4 ± 7.0</td>
<td>0.440</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>27.3 ± 1.2</td>
<td>36.2 ± 5.1</td>
<td>0.000</td>
</tr>
<tr>
<td>Body fat – BIA (%)</td>
<td>34.6 ± 3.6</td>
<td>41.0 ± 3.0</td>
<td>0.000</td>
</tr>
<tr>
<td>Body fat – BIA (kg)</td>
<td>24.0 ± 3.7</td>
<td>37.0 ± 8.6</td>
<td>0.000</td>
</tr>
<tr>
<td>Body fat – Segal equation (%)</td>
<td>30.3 ± 2.1</td>
<td>46.0 ± 2.6</td>
<td>0.000</td>
</tr>
<tr>
<td>Body fat – Segal equation (kg)</td>
<td>21.0 ± 3.1</td>
<td>41.4 ± 8.9</td>
<td>0.000</td>
</tr>
</tbody>
</table>

†: p<0.05 vs overweight.

BMI: body mass index, BIA: bioelectric impedance analysis.

![Fig. 1.—Body fat percentage estimated by bioelectrical impedance analysis and Segal equation et al (1988) by body mass index (overweight vs obesity).](image)
study of BIA devices, sum of skinfolds and hydrostatic weighing, the authors found significant differences between the %BF obtained by the Biodynamics A-310® and the Malron BF-906® devices when compared to the hydrostatic weighing. It did not happen when the BIA devices were compared to each other. For the authors, these differences found may be associated to the error when the device measured the impedance, to the error when choosing the equation to be used, to the lack of specificity of the equation used for the sample or to the combination of one or more of these reasons. Such limitations have also been identified in this study since the Biodynamics® model 450 device does not describe in its manual the equation used.

In the study of Shafer et al23, the %BF obtained by BIA was compared to that of dual energy x-ray absorptiometry (densitometry), and it was possible to notice that BIA underestimated the %BF in obese individuals (0.75%; p<0.006), underestimated it in eutrophic individuals (-1.56%; p<0.0001), but with no difference in overweight individuals. In the present study, BIA overestimated the %BF in overweight women and underestimated it in obese women.

Rossi & Tirapegui30 have found a high correlation between the %BF values in two BIA models (Biodynamics® - model 310 and Tanita® electronic scales - model 2001B-W); however, when they compared the BIA values to the anthropometric equation of Faulkner,3 it underestimated the values of %BF. This is likely to be due to the fact that this equation is recommended to swimmers.

Studies on the validation of equations have been developed in several bipolar and tetrapolar BIA devices. The disagreement between the studies may be due to the variance of the equations and equipment used, the adoption of different protocols, different ethnic groups and body composition, as well as influence on the state of hydration. In Brazil, Marques et al20 found that the equations of Lohman4 and of Stolarczyk et al5 can be used in the assessment of young Brazilian women’s body composition. In the present study, the equation of Segal et al13 becomes the most accurate in overweight women.

We found that the reference methods employed in assessing body composition (BIA) in this study may be sufficiently accurate in overweight and obese women. Because, the Segal13 equation was developed for women whose BMI is >30kg/m² or %BF >30%, when evaluated by densitometry. Thus, the present study and Segal et al13 shows optimal BIA prediction equation for evaluation of %BF in overweight and obese women.

Rech et al24 analyzed four methods for assessing body fat in women over 50 years old and compared the models of BIA Biodynamics® and ONROMâ® to the equations proposed by Jackson et al25 and Durnin & Womersley.26 The results showed that the equation of Jackson et al25 demonstrated greater validity for the estimate of the %BF in elderly women. The equation of Durnin & Womersley26 and Biodynamics® tetrapolar BIA did not seem to be valid for the estimate of %BF whereas ONROMâ® bipolar BIA was the only method tested that demonstrated significant validity for the estimate of %BF.

The study of Glaner31 used the equation of Segal et al13 and verified validity of this formula in other individuals (Brazilian military men). It is important to highlight that the equation of Segal et al13 was developed aiming men whose %BF was higher than 20%. Another Brazilian study27, found that the estimates of %BF were overestimated both in men and in women when compared to BIA. In this study, BIA showed variable effectiveness according to BMI.

The possible limitation of this study would be the lack of one more group of women, the eutrophic ones, once it would be interesting to check if the results obtained would also agree with the ones of overweight or obese women. Moreover, there is the need of comparing the %BF obtained by BIA and by the equation to the gold standard, which is densitometry.

Although differences on the %BF by the two methods have been found, these do not cause consequences to the biological interpretation of the values for the individuals. However, the clinicians must be aware of using the best method and being cautious when informing the diagnosis of the body fat amount to the patient.

Conclusion

It is possible to observe that in overweight women, BIA overestimates the %BF while it underestimates it in obese women. Thus, this study suggests that the use of resistance, provided by BIA followed by the calculation of %BF by the equation of Segal et al13 becomes the most reliable method for estimating the %BF. However, more studies are necessary, especially on the development of specific equations not only for different populations but also for the use in different equipment, and also on the search of their basic presuppositions in order to minimize their limitations. In addition, the results of previous studies evidence the difficulty in establishing some kind of conclusion about the validity of BIA in Brazilian individuals because of different approaches used, age groups, nutritional status, and mainly the equations used and the lack of study in this area in Brazil.

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References


