Body fat estimated by equations based on anthropometric parameters correlates with bioelectrical impedance in patients undergoing bariatric surgery

Amanda Motta de Bortoli\textsuperscript{a}; Beatriz Bobbio de Brito\textsuperscript{b}; Luís Lucas Vasconcelos Neves\textsuperscript{c}; Ricardo Lucio de Almeida\textsuperscript{d}; Leandro dos Santos\textsuperscript{c}; Valério Garrone Barauna\textsuperscript{e}; Fabiano Kenji Haraguchi\textsuperscript{a,b}

Abstract

Introduction: predictive equations to estimate body fat based on simple anthropometric parameters are easy to use in the clinical practice.

Objective: to evaluate the relationship between predictive equations based on anthropometric parameters and bioelectrical impedance to estimate body fat in individuals undergoing bariatric surgery.

Methods: a prospective and longitudinal study carried out with individuals undergoing bariatric surgery. Body weight, body mass index, waist circumference and body fat percentage estimated by anthropometric parameters and by impedance were evaluated at three moments, one month before, two and six months after surgery. Data were analyzed by one-way ANOVA for repeated measures with Holm-Sidak’s post hoc or Friedman test with Tukey’s post hoc, and Pearson or Spearman correlations, according to data distribution. Significance level adopted 5%.

Results: twenty-five subjects composed the final sample. All anthropometric parameters reduced significantly over time ($p<0.001$). Except for Lean et al equation before surgery, the body fat percentage estimated by other formulas showed a strong correlation with impedance in all moments, with the highest correlation strength observed in Gómez-Ambrosi et al. equation.

Conclusion: in the present study, the equations used showed a good correlation with bioelectrical impedance, and the Gómez-Ambrosi et al. equation as a better option to the use of bioimpedance to assess changes in body fat percentage of patients undergoing bariatric surgery for the treatment of severe obesity.

Keywords: obesity, body composition, electric impedance, anthropometry
Developed from a significant sample of individuals (12,581, Woolcott & Bergman) parameters to be evaluated. The equation developed by the variables height, weight, BMI, age and sex, simple

et al. Among these, the equations developed by Deurenberg are easy to use and low cost.

Clinical practice unfeasible. Which would make its use in larger groups or even in

Higher than those based on anthropometric parameters, errors

temperature, among others, which allow measurement

Such as diet, hydration level, menstrual cycle, ambient
to hydrogen energy x-ray emission densitometry (DXA)

Gold standard, such as hydrostatic weighing and dual

Densitometry (impedance) to the passage of electric current

That estimates the percentage of body of the evaluated, and is based on the fact that the body tissues offer different oppositions (impedance) to the passage of electric current[8-10]. Studies demonstrate the accuracy of BIA as a method for determining %BF when compared to methods considered gold standard, such as hydrostatic weighing and dual energy x-ray emission densitometry (DXA)[11,12]. However, BIA has the disadvantage of depending on control factors such as diet, hydration level, menstrual cycle, ambient temperature, among others, which allow measurement errors[13]. In addition, the cost per assessment is relatively higher than those based on anthropometric parameters, which would make its use in larger groups or even in clinical practice unfeasible.

As an alternative tool, %BF predictive equations based on anthropometry are easy to use and low cost. Among these, the equations developed by Deurenberg et al.[14]; Lean et al.[15] and Gómez-Ambrosi et al.[16] use the variables height, weight, BMI, age and sex, simple parameters to be evaluated. The equation developed by Woolcott & Bergman[17] uses only the variables gender, waist circumference (WC) and height.

The equations proposed by Woolcott & Bergman, Gómez-Ambrosi et al.[16] and Deurenberg et al.[14] were developed from a significant sample of individuals (12,581, 6,123 and 1,229 participants, respectively). Although most of the evaluated participants were eutrophic, the samples were also composed of overweight individuals, who showed a wide variation in %BF[14-17]. In addition, all formulas were compared with methods considered reference in the analysis of body composition, such as hydrostatic weighing[15,16], DXA[17] and plethysmography[16]. However, studies evaluating the relationship between the %BF estimated by these formulas and BIA during BS-induced body fat loss are less known.

Based on this information, the present study aimed to evaluate the relationship between predictive equations based on anthropometric parameters and BIA to estimate body fat in individuals undergoing BS.

■ MATERIAL AND METHODS

Sample and study design

A longitudinal and prospective study, carried out with adult individuals of both sexes, enrolled in the Bariatric and Metabolic Surgery Program of the Cassiano Antônio Moraes University Hospital (HUCAM), Espírito Santo, Brazil. The sample was selected for convenience, according to the criteria for performing Roux-en-Y Gastric Bypass: age between 18-60 years, BMI > 40kg/m or >35Kg/m with associated comorbidities. Pregnant women, individuals with pacemakers and those with metallic structures and/or silicone prostheses were excluded[18]. The study was approved by the Research Ethics Committee of the Hospital (CAAE nº 59075722.7.0000.5071), and the research participants consented to participate by signing the Free and Informed Consent Form. All procedures were performed in accordance with the World Medical Association’s code of ethics (Declaration of Helsinki).

Participants were evaluated at three times: approximately 1 month before (T0), 2nd (T1) and 6th months (T2) after surgery. Anthropometric assessment and BIA were performed during the program’s clinical follow-up consultations.

Anthropometric parameters

Body weight was measured on an anthropometric scale, with a capacity of 300 kg and precision of 0.05 kg;
height was measured with the aid of a wall stadiometer, with a graduation of 0.1 cm. BMI was calculated using the formula: body weight (kg)/height² (m). Waist circumference (WC) was measured in centimeters, over the umbilical scar.

**Electrical bioimpedance**

The assessment of body fat by BIA was performed in tetrapolar equipment, brand Biodynamics®, model 450, following the recommendations of the European Society of Clinical Nutrition and Metabolism. Fat-free mass was calculated using the formula for people with obesity, proposed by Segal et al., and fat mass was calculated as the difference in total body weight, and expressed as a percentage.

**Predictive equations**

The following predictive equations were used: Woolcott & Bergman, Deurenberg et al., Lean et al., and Gómez–Ambrosi et al. The equations for calculating the %BF are shown in table 1.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Sex</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woolcott &amp; Bergman (2018)</td>
<td>M</td>
<td>%BF = 64-(20 x height/WC)</td>
</tr>
<tr>
<td>F</td>
<td>%BF= 76-(20 x height/WC)</td>
<td></td>
</tr>
<tr>
<td>Deurenberg et al. (1991)</td>
<td>M</td>
<td>%BF = 1.2 x BMI + 0.23 x (age) – (10.8 x 1) -5.4</td>
</tr>
<tr>
<td>F</td>
<td>%BF = 1.2 x BMI + 0.23 (age) - (10.8 x 0) - 5.4</td>
<td></td>
</tr>
<tr>
<td>Lean et al. (1996)</td>
<td>M</td>
<td>%BF = (1.33 x BMI) + (0.236 x age) -20.2</td>
</tr>
<tr>
<td>F</td>
<td>%BF = (1.21 x BMI) + (0.262 x age) - 6.7</td>
<td></td>
</tr>
<tr>
<td>Goméz–Ambrosi et al. (2012)</td>
<td>M</td>
<td>%BF = -44.988 + (0.503 x age) + (10.689 x 0) + (3.172 x BMI) - (0.026 x BMI²) + (0.181 x BMI x 0) - (0.005 x BMI² x 0) + (0.00021 x BMI² x age)</td>
</tr>
<tr>
<td>F</td>
<td>%BF = -44.988 + (0.503 x age) + (10.689 x 1) + (3.172 x BMI) - (0.026 x BMI²) + (0.181 x BMI x 1) - (0.02 x BMI x age) - (0.005 x BMI² x 1) + (0.00021 x BMI² x age)</td>
<td></td>
</tr>
</tbody>
</table>

F: female; M: male; WC: waist circumference; BMI: body mass index; BF: body fat.

**Statistical analysis**

Data were analyzed by the Shapiro Wilk normality test, and later by the one-way ANOVA for repeated measures with Holm-Sidak post hoc or Friedman test with Tukey post hoc, according to the data distribution. The correlations between the data obtained by the BIA and the equations at each moment were evaluated using the Pearson or Spearman correlation, according to the data distribution, and classified as: weak (0.30 to 0.50); moderate (0.50 to 0.70); strong (0.70 to 0.90); very strong (>0.90). The Statistical Package for the Social Sciences - SPSS, version 22.0 software was used. The significance level adopted was 5% (p < 0.05).

**RESULTS**

Twenty-five individuals who attended the three scheduled assessments participated in the study. A predominance of females (75%) was observed. Participants were, on average, 41.2 ± 7.8 years old and 162.0 ± 8.7 cm tall. The evaluations took place at approximately 24.0 ± 20.5 days before (T0), 72.0 ± 19.5 (T1) and 189.0 ± 12.2 (T2) days after the BS. The values of body weight, BMI, WC, and % BF estimated by BIA and the equations of Woolcott & Bergman and Gómez–Ambrosi et al. showed normal distribution, while the values of % BF estimated by the equation of Deurenberg et al. and Lean et al. showed non-normal distribution.

Table 2 shows the changes in anthropometric parameters over time. Weight, BMI, WC significantly reduced at all times (p<0.05). Table 3 shows the % BC estimated by the BIA and the predictive equations used. The %BF estimated by BIA and by the equations of Woolcott & Bergman and Gómez–Ambrosi et al. significantly reduced at T1 and remained at T2 (p<0.05). The %BF estimated by the Woolcott & Bergman17 equation was significantly reduced only in T2 (p<0.05), while the %BF estimated by the equations of Deurenberg et al. and Lean et al.15 differed significantly at all times (p<0.05).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>T0</th>
<th>T1</th>
<th>T2</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (kg)</td>
<td>110,2</td>
<td>93,6</td>
<td>80,7</td>
<td>&lt;0,001</td>
</tr>
<tr>
<td>(98,5 - 126,7)</td>
<td>(83,0 - 108,1)</td>
<td>(71,9 - 92,5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>43,3</td>
<td>35,2</td>
<td>31,6</td>
<td>&lt;0,001</td>
</tr>
<tr>
<td>(39,2 - 48,0)</td>
<td>(32,5 - 41,2)</td>
<td>(28,5 - 34,9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WC (cm)</td>
<td>119</td>
<td>106,5</td>
<td>96,9</td>
<td>&lt;0,001</td>
</tr>
<tr>
<td>(111,0 - 128,1)</td>
<td>(103,7 - 120,3)</td>
<td>(86,7 - 106,4)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

BMI: body mass index; WC: waist circumference. N = 25. T0: 24.0 ± 20.5 days before surgery; T1: 72.0 ± 19.5 days after surgery; T2: 189.0 ± 12.2 days after surgery. Values expressed as median (interquartile range) and analyzed using Friedman’s test and Tukey’s post hoc test.
Correlations between BIA estimated %BF values and predictive equations are shown in Figures 1–3. Before surgery (figure 1), the %BF estimated by the equation of Gómez–Ambrosi et al. showed the strongest correlation with BIA (r=0.9198; p<0.001), followed by the equations of Woolcott & Bergman (r=0.8215; p<0.001), Deurenberg et al. (r=0.7792; p<0.001) and Lean et al. (r=0.6949; p<0.001), a result that remained for approximately two months after BS (figure 2). The equation by Gómez–Ambrosi et al. continued to show the strongest correlation with BIA values about six months after BS (r = 0.9294; p<0.001) (figure 3), followed by Deurenberg’s equations and Lean et al. and Woolcott & Bergman. At all times, the Gómez–Ambrosi et al. equation showed a very strong correlation with BIA.

### Table 3: Percentage of body fat estimated by BIA and predictive equations at different times

<table>
<thead>
<tr>
<th>Method</th>
<th>T0</th>
<th>T1</th>
<th>T2</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIA (%)</td>
<td>47.9</td>
<td>(44.6 - 49.5)</td>
<td>43.9</td>
<td>(39.8 - 46.0)</td>
</tr>
<tr>
<td>Woolcott &amp; Bergman (2018) (%)*</td>
<td>47.4</td>
<td>44.8</td>
<td>39.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Deurenberg et al. (1991) (%)**</td>
<td>54.32 ± 7.35a</td>
<td>45.97 ± 7.24b</td>
<td>40.4 ± 6.94c</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Lean et al. (1996) (%)**</td>
<td>55.11 ± 7.48b</td>
<td>46.51 ± 7.39b</td>
<td>40.8 ± 7.1c</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Gómez-Ambrosi et al. (2012) (%)*</td>
<td>52.5</td>
<td>46.3</td>
<td>42.2</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

BIA: bioelectrical impedance. N=25. T0: 24.0 ± 20.5 days before surgery; T1: 72.0 ± 19.5 days after surgery; T2: 189.0 ± 12.2 days after surgery. *Values expressed as median (interquartile range) and analyzed using Friedman’s test and Tukey’s post hoc test. **Values expressed as mean ± Standard deviation and analyzed by the ANOVA test for repeated measures and Holm-Sidak post hoc. Different letters on the same line represent significantly different values between moments (p<0.05).

Figure 1: Correlation between body fat percentage (%BF) estimated by bioelectrical impedance (BIA) and predictive formulas (A) Gómez-Ambrosi et al., (B) Woolcott & Bergman, (C) Deurenberg et al. and (D) Lean et al. at T0, 24.0 ± 20.5 days before surgery.
Figure 2: Correlation between body fat percentage (%BF) estimated by bioelectrical impedance (BIA) and predictive formulas (A) Gómez-Ambrosi et al., (B) Woolcott & Bergman, (C) Deurenberg et al. and (D) Lean et al. at T1, 72.0 ± 19.5 after surgery.

Figure 3: Correlation between the percentage of body fat (%BF) estimated by bioelectrical impedance (BIA) and predictive formulas (A) Gómez-Ambrosi et al., (B) Woolcott & Bergman, (C) Deurenberg et al. and (D) Lean et al. at T2, 189.0 ± 12.2 (T2) days after surgery.
DISCUSSION

In the present study, with the exception of the equation by Lean et al.15 before BS, all formulas showed a strong correlation with BIA, and the values obtained by the equation by Gómez-Ambrosi et al.16 showed the highest correlation strength in the three moments evaluated.

The predictive equations used in the present study use simple and easy-to-collect anthropometric data, being useful for use in clinical practice, without the need for sophisticated equipment, and in cases in which skinfold measurements are more difficult, such as in individuals with severe obesity.20 These equations were developed and validated through samples with a large number of individuals with a wide age range, and compared with reference methods such as plethysmography16, hydrostatic weighing14,15 and DXA17.

The high correlation values observed between the equation by Gómez-Ambrosi et al.16 and BIA, before and after BS, corroborate other studies carried out using different reference methods, such as DXA and plethysmography12,13. The equation by Gómez-Ambrosi et al., also described as CUN-BAE (Clinic Universidad de Navarra-Body Adiposity Estimator), was developed with the aim of increasing accuracy in estimating body fat. The formula was derived from data from 6,123 participants with a mean BMI of 31.6 kg/m², a broad age range (18-80 years) and adiposity (2.1 – 69.6%). Furthermore, Gómez-Ambrosi et al.16 included individuals with a high BMI (maximum of 72.8 kg/m²), while Deurenberg et al.14 and Lean et al.15 used individuals with a maximum BMI of 40.9 kg/m² and 41.2 kg/m², respectively. In addition, the sample used by Gómez-Ambrosi et al.16 was composed mostly of women (68%), similarly to the present study. These factors may, in part, explain the greater strengths of correlation found between the formula by Gómez-Ambrosi et al.16 and the BIA.

The equation proposed by Woolcott & Bergman17 was developed from the evaluation of 6,320 men and 6,261 women, with an estimated average percentage of total body fat of 28 and 40%, respectively. In the present study, despite the %BF estimated by this formula having presented greater numerical similarity with the %BF estimated by the BIA, the strength of the correlation of this formula with the BIA values was greater after the BS, moments in which the participants presented %BF smaller and more similar to the profile of the 12,581 individuals evaluated by the aforementioned authors, suggesting that, as the %BF decreases, there is a tendency towards an increase in the precision of the formula, also known as Relative Fat Mass. Guzmán-León et al.21 also found a strong correlation between the %BF estimated by the Relative Fat Mass and the DXA in 61 eutrophic young Mexicans. However, excess abdominal fat can make it difficult to measure WC in morbidly obese individuals, which could interfere with the estimation of body composition.

Similarly, there was an increase in the strength of the correlation between the Deurenberg et al.14 equation and BIA after BS, especially after six months, when the participants had lower BMI values. In a previous study, Martins et al.11 observed a strong correlation between the %BF values estimated by the Deurenberg et al.14 equation with data obtained by DXA in individuals with grade I obesity. The lowest correlation values presented by the Deurenberg et al.14 with BIA at times when individuals had a higher %BF may also be partly related to the wide variation in the age range of the population in which this equation was validated, which was between 7 and 83 years of age.14 However, the results of the present study corroborate the results of the study by Lopes et al.15, who evaluated % BF by BIA in 27 young people with obesity, and observed a discrepancy in the values estimated by the equation by Deurenberg et al.14.

Regarding the equation by Lean et al.15, greater differences were observed in relation to BIA to estimate the %BF in individuals with a high degree of adiposity (before BS), suggesting that the equation of Lean et al.15 can be more indicated for eutrophic or overweight individuals, as observed by Silveira et al.22 who compared different formulas with DXA, and observed that the best agreement in overweight men was with the equation proposed by Lean et al.15.

The reduction in anthropometric measurements over time reinforces the role of BS in the treatment of morbid obesity, as observed in other studies23-25. As a consequence of changes in body composition, the reduction in adiposity promoted by BS results in significant changes in the inflammatory state associated with obesity, with an improvement in the general health status of individuals.26,27

The use of equations based on simple, easy-to-measure anthropometric parameters can be advantageous in the assessment of larger population groups, or even in follow-up consultations for bariatric patients, since they do not require sophisticated equipment and do not depend on skinfold measurements, which may be impractical in morbidly obese individuals. However, some limitations should be mentioned: the evaluations were carried out in the follow-up consultations, which made it difficult for them to occur at the planned times. In addition, participants’ dropouts throughout the study contributed, in part, to the small sample size.

CONCLUSION

In view of the results obtained, it is concluded that all the equations used showed a strong correlation with the BIA, with the exception of Lean et al.15 before the BS. The equation by Gómez-Ambrosi et al.16 presented the highest correlation strengths with BIA at the three evaluated moments, being, in the present study, the best alternative to the use of BIA to assess changes in %BF during the follow-up of patients undergoing BS for the treatment of severe obesity.

Special Thanks

To the National Council for Scientific and Technological Development (CNPQ), the Coordination for the Improvement of Higher Education Personnel (CAPES), the Fundação de Amparo à Pesquisa e Inovação do Espírito Santo (FAPES), and the Cassiano Antônio Moraes University Hospital (HUCAM).
Financing


Conflict of interest

The authors declare no conflict of interest.

Authors’ contribution

Study design: Haraguchi FK; Data collection, analysis and interpretation: Bortoli AM, Brito BB, Neves LLV, Almeida RL, Santos L, Barauna VG; Writing of the manuscript: Bortoli AM, Brito BB, Neves LLV, Almeida RL, Santos L, Barauna VG and Haraguchi FK; Review and approval of the manuscript for submission: Bortoli AM, Brito BB, Neves LLV, Almeida RL, Santos L, Barauna VG and Haraguchi FK.

REFERENCES

Resumo

Introdução: equações preditivas que estimam o percentual de gordura baseadas em parâmetros antropométricos simples são de fácil utilização na prática clínica.

Objetivo: avaliar a relação entre equações preditivas baseadas em parâmetros antropométricos e a bioimpedância elétrica para estimar a gordura corporal de indivíduos submetidos à cirurgia bariátrica.

Método: estudo prospectivo e longitudinal, realizado com indivíduos submetidos à cirurgia bariátrica. Peso corporal, índice de massa corporal, circunferência da cintura e o percentual de gordura corporal estimado por parâmetros antropométricos e pela bioimpedância foram avaliados em três momentos, 1 mês antes, no 2º e 6º meses após a cirurgia. Os dados foram analisados pela ANOVA de uma via para medidas repetidas com post hoc de Holm-Sidak ou teste de Friedman com post hoc de Tukey, e correlações de Pearson ou Spearman, de acordo com a distribuição dos dados. Nível de significância adotado 5%.

Resultados: participaram do estudo 25 pacientes. Todos os parâmetros antropométricos reduziram significativamente ao longo dos momentos (p<0.001). Com exceção da equação de Lean e colaboradores antes da cirurgia, o percentual de gordura estimado pela bioimpedância foram avaliados em três momentos, 1 mês antes, no 2º e 6º meses após a cirurgia. Os dados foram analisados pela ANOVA de uma via para medidas repetidas com post hoc de Holm-Sidak ou teste de Friedman com post hoc de Tukey, e correlações de Pearson ou Spearman, de acordo com a distribuição dos dados. Nível de significância adotado 5%.

Conclusão: no presente estudo, as equações utilizadas apresentaram boa correlação com a bioimpedância para avaliar as alterações da gordura corporal de pacientes submetidos a cirurgia bariátrica para o tratamento da obesidade grave.

Palavras-chave: obesidade, composição corporal, impedância elétrica, antropometria.