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ORIGINAL ARTICLE

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

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Open acess

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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

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Authors summary

Why was this study done?
Individuals undergoing bariatric surgery may present important changes in body composition, highlighting the importance of simple and low-cost methods for the assessment of body fat percentage. Electrical bioimpedance is a method that estimates the percentage of body fat, however it depends on control factors such as food, hydration level, menstrual cycle, ambient temperature, and also the high cost of equipment that could make its use in practice unfeasible clinic.
In this context, the purpose of the present study was to evaluate the relationship between predictive equations based on anthropometric parameters, which are easy to use and low cost, and electrical bioimpedance to estimate body fat in individuals undergoing bariatric surgery.

What did the researchers do and find?
In this study, we evaluated the correlation between body fat estimated by equations based on simple anthropometric parameters, such as weight, body mass index and waist circumference, and fat estimated by bioelectrical impedance in severely obese patients undergoing bariatric surgery.
Body fat estimated by the formulas showed a strong correlation with bioimpedance before and after surgery, with the highest correlation strength observed in the equation by Gómez-Ambrosi *et al*.

What do these findings mean?
The findings of the present study suggest that the Gómez-Ambrosi et al. equation may be the best alternative to the use of bioimpedance to assess changes in body fat during the follow-up of individuals undergoing bariatric surgery.

INTRODUCTION

Obesity is a chronic condition characterized by the abnormal or excessive accumulation of body fat, responsible for compromising the health of individuals[1-3]. Bariatric surgery (BS) is considered an important strategy for the treatment of severe refractory obesity[4]. However, during the first six months after BS, the period of the rapid weight loss phase, individuals undergoing BS may present significant changes in body composition[5,6]. In this context, from a clinical and public health perspective, the use of simple, low-cost methods are of great relevance for the assessment of the percentage of body fat (%BF) of these individuals[7].

The bioelectrical impedance (BIA) is a method that estimates the %BF in a non-invasive, safe and fast way, which consists in the application of a low frequency electric current by the 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[17], 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)/height^2 (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[18]. Fat-free mass was calculated using the formula for people with obesity, proposed by Segal *et al.*[9], 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[17], Deurenberg *et al.*[14], Lean *et al.*[15] and Gómez – Ambrosi *et al.*[16]. The equations for calculating the %BF are shown in table 1.

Table 1: Predictive equations of body fat percentage used in the study

Reference	Sex	Equation
Woolcott & Bergman (2018)	M	%BF = 64-(20 x height/WC)
	F	%BF= 76-(20 x height /WC)
Deurenberg *et al*. (1991)	M	%BF = 1.2 x BMI + 0.23 x (age) – (10.8 x 1) -5.4
	F	%BF = 1.2 x BMI + 0.23 (age) - (10,8 x 0) - 5.4
Lean et al. (1996)	M	%BF = (1.33 x BMI) + (0.236 x age) -20.2
	F	%BF = (1.21 x BMI) + (0.262 x age) - 6.7
Goméz-Ambrosi *et al*. (2012)	M	%BF = -44.988 + (0.503 x age) + (10.689 x 0) + (3.172 x BMI) - (0.026 x BMI²) + (0.181 x BMI.0) - (0.02 x BMI x age) - (0.005 x BMI² x 0) + (0.00021 x BMI² x age)
	F	%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)

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)[19]. 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 by the equations of Woolcott & Bergman[17] and Gómez-Ambrosi *et al.*[16] showed normal distribution, while the values of % BF estimated by the equation of Deurenberg *et al.*[14] and Lean *et al.*[15] showed non-normal distribution.

Table 2 shows the changes in anthropometric parameters over time. Weight, BMI and 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 equation by Goméz-Ambrosi *et al.*[16] 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.*[14] and Lean *et al.*[15] differed significantly at all times ($p< 0.05$).

Table 2: Anthropometric parameters evaluated at different times

Parameter	T0	T1	T2	p value
Weight (kg)	110,2	93,6	80,7	<0,001
	(98,5 - 126,7)[a]	(83,0 - 108,1)[b]	(71,9 - 92,5)[c]	
BMI (kg/m²)	43,3	35,2	31,6	<0,001
	(39,2 - 48,0)[a]	(32,5 - 41,2)[b]	(28,5 - 34,9)[c]	
WC (cm)	119	106,5	96,9	<0,001
	(111,0 - 128,1)[a]	(103,7 - 120,3)[b]	(86,7 - 106,4)[c]	

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.

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

Method	T0	T1	T2	P value
BIA (%)*	47,9	43,9	39,6	<0,001
	(44,6 - 49,5)[a]	(39,8 - 46,0)[b]	(35,9 - 43,3)[b]	
Woolcott & Bergman (2018) (%)*	47,4	44,8	39,5	<0,001
	(44,0 - 50,4)[a]	(40,6 - 48,1)[a]	(36,2 - 44,7)[b]	
Deurenberg et al. (1991) (%)**	54,32 ± 7,35[a]	45,97 ± 7,24[b]	40,4 ± 6,94[c]	<0,001
Lean *et al.* (1996) (%)**	55,11 ± 7,48[a]	46,51 ± 7,39[b]	40,8 ± 7,1[c]	<0,001
Gómez-Ambrosi *et al.* (2012) (%)*	52,5	46,3	42,2	<0,001
	(49,7 - 55,0)[a]	(43,6 - 50,6)[b]	(37,9 - 46,2)[b]	

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).

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.*[16] showed the strongest correlation with BIA (r=0.9198; p<0.001), followed by the equations of Woolcott & Bergman[17] (r=0.8215; p<0.001), Deurenberg *et al.*[14] (r=0.7792; p <0.001) and Lean *et al.*[15] (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.*[16] 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 *et al.*[14], Lean *et al.*[15] and Woolcott & Bergman[17]. At all times, the Gómez–Ambrosi *et al.*[16] equation showed a very strong correlation with BIA.

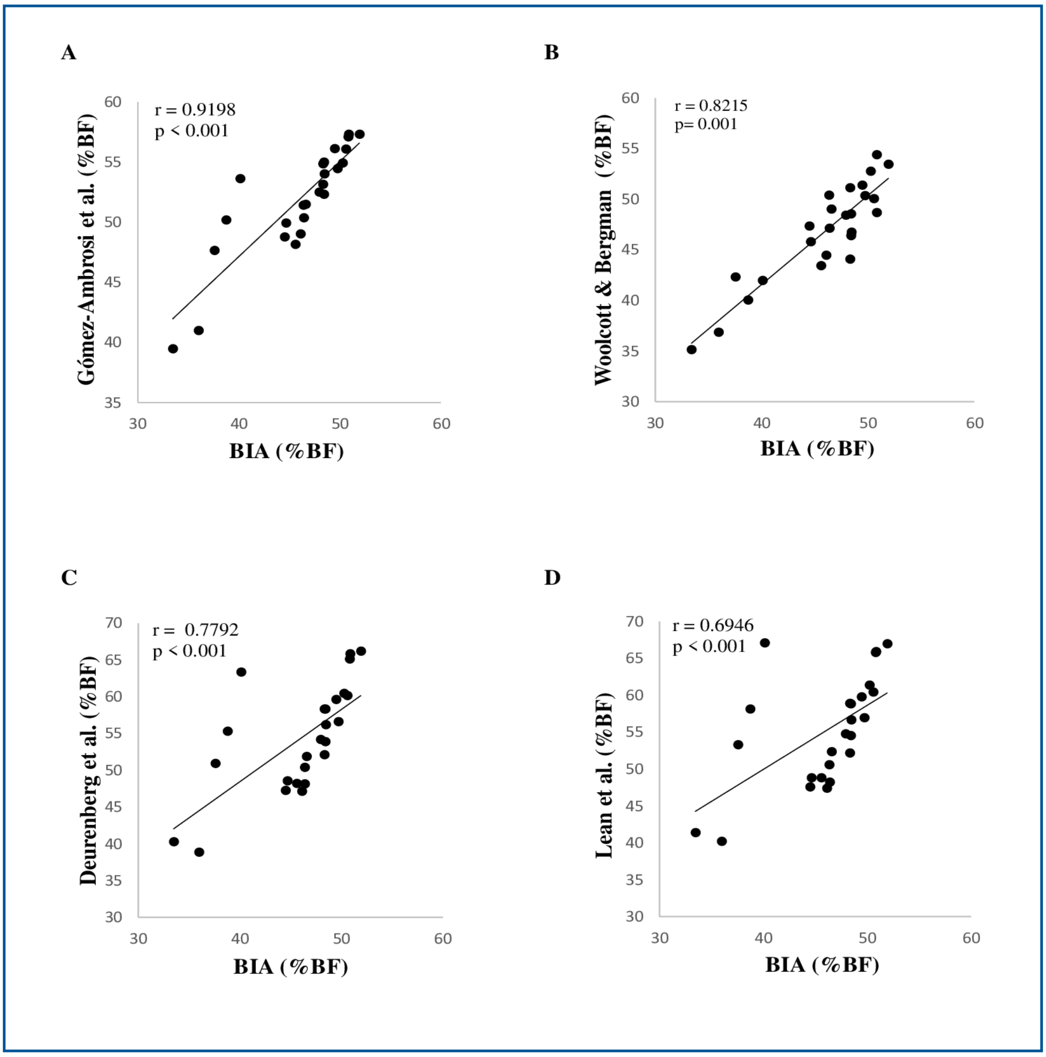

Figure 1: Correlation between body fat percentage (%BF) estimated by bioelectrical impedance (BIA) and predictive formulas (A) Gómez-Ambrosi *et al.*, (B) Woolcott & Bergman, (C) Deurenberg *et al.* and (D) Lean *et al.* at T0, 24.0 ± 20.5 days before surgery

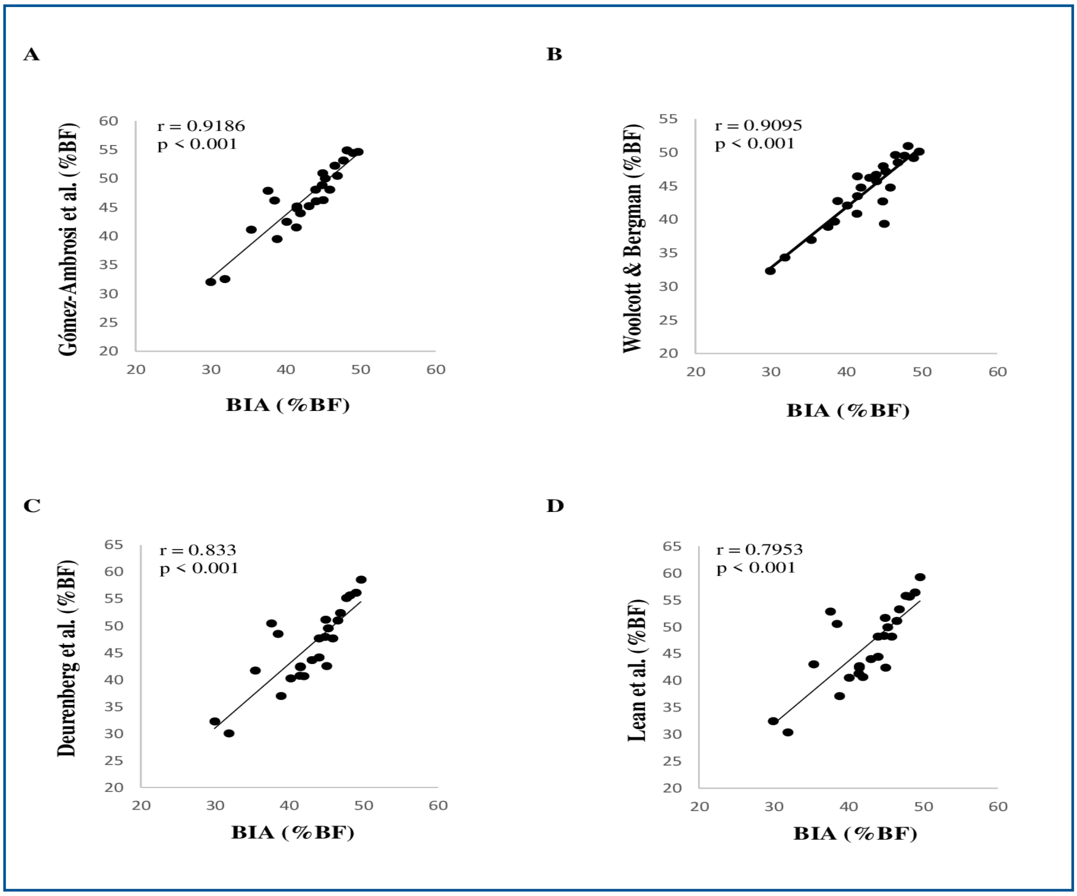

Figure 2: Correlation between body fat percentage (%BF) estimated by bioelectrical impedance (BIA) and predictive formulas (A) Gómez-Ambrosi *et al.*, (B) Woolcott & Bergman, (C) Deurenberg *et al*. and (D) Lean *et al*. at T1, 72.0 ± 19.5 after surgery

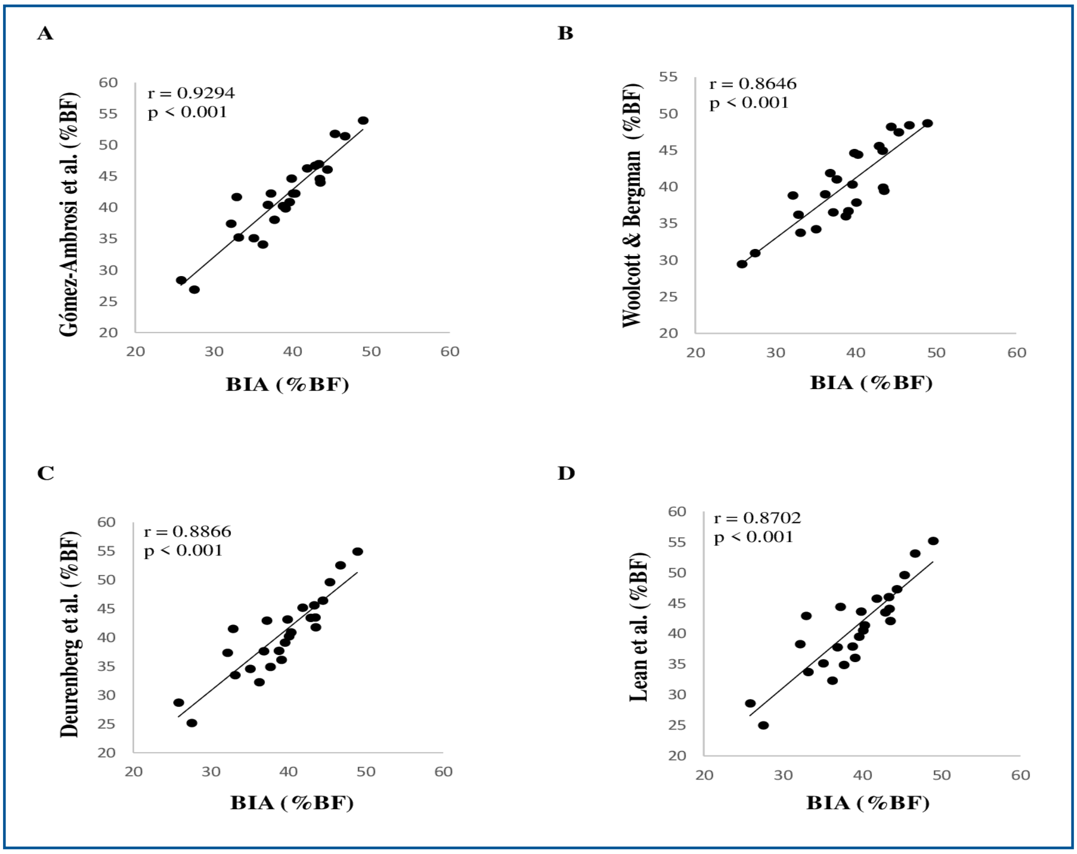

Figure 3: Correlation between the percentage of body fat (%BF) estimated by bioelectrical impedance (BIA) and predictive formulas (A) Gómez-Ambrosi *et al*., (B) Woolcott & Bergman, (C) Deurenberg *et al*. and (D) Lean *et al.* at T2, 189.0 ± 12.2 (T2) days after surgery

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 plethysmography[16], hydrostatic weighing[14,15] and DXA[17].

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 plethysmography[12,13]. The equation by Gómez-Ambrosi *et al.*[16], 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/m^2, 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/m^2), while Deurenberg *et al.*[14] and Lean *et al.*[15] used individuals with a maximum BMI of 40.9 kg/m^2 and 41.2kg/m^2, 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 & Bergman[17] 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 Mas. 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.*[13] 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.*[11], 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 studies[23-25]. 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.

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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.

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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 pelas demais fórmulas apresentaram forte correlação com a bioimpedância em todos os momentos, com a maior força de correlação observada na equação de Gómez-Ambrosi e colaboradores.

Conclusão: no presente estudo, as equações utilizadas apresentaram boa correlação com a bioimpedância, sendo a equação de Gómez-Ambrosi a melhor alternativa ao uso da 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.