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Original Article

Validation of a bioelectrical impedance scale for the estimation of body fat in adolescents

Validação de uma balança de impedância bioelétrica para a estimativa de gordura corporal em adolescentes

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ABSTRACT

Introduction: Several different instruments available on the market have been used for the estimation of body fat. However, many of these instruments have not been compared with reference criteria to verify their true accuracy.
Aim: to verify the validity of a bioelectrical impedance scale (OMRON-514C) for the estimation of body fat.
Methods: Forty-four overweight adolescents (25 females) participated in this study, with an average age of 12.3 ± 1.1 years. All were submitted to body fat evaluations by air displacement plethysmography and bioelectrical impedance.
Results: Higher values of relative and absolute body fat were estimated by bioelectrical impedance compared to plethysmography ($p < 0.05$). There was no correlation between the relative body fat measurements between the two methods ($r = 0.185$; $p = 0.228$). The absolute measurements of body fat were correlated ($r = 0.497$, $p = 0.001$). Both in the measurements of relative ($p= 0.034$) and absolute body fat ($p = 0.021$), the bioelectrical impedance overestimated the measured values.
Conclusion: in adolescents with characteristics like the present study, the estimate of body fat by the bioelectrical impedance (OMRON-514C) should be used with caution.

Key-words: Plethysmography, Bioelectrical impedance, Adolescents, Overweight.

RESUMO

Introdução: A estimativa da gordura corporal tem sido realizada por diversos equipamentos disponíveis no mercado. Entretanto, muitos desses equipamentos não foram comparados com critérios de referência que verificassem a sua real acurácia.
Objetivo: Verificar a validade de uma balança de impedância bioelétrica (OMRON-514C) para a estimativa de gordura corporal.
Métodos: Quarenta e quatro adolescentes com excesso de peso (25 do sexo feminino) participaram deste estudo, com idade média de 12,3 ± 1,1 anos. Todos foram submetidos à avaliação da gordura corporal por pletismografia de deslocamento de ar e impedância bioelétrica.
Resultados: Valores mais elevados de gordura corporal relativa e absoluta foram estimados por impedância bioelétrica em relação à pletismografia ($p < 0,05$). Não houve correlação entre as medidas de gordura corporal relativa entre os dois métodos ($r = 0,185$; $p = 0,228$). As medidas absolutas de gordura corporal foram correlacionadas ($r = 0,497$, $p = 0,001$). Tanto nas medidas de gordura corporal relativa ($p = 0,034$) quanto absoluta ($p = 0,021$), nas quais, para ambas as medidas, a impedância bioelétrica superestimou os valores medidos.
Conclusão: em adolescentes com características semelhantes a do presente estudo, a estimativa de gordura corporal pela impedância bioelétrica (OMRON-514C) deve ser usada com cautela.

Palavras-chave: Pletismografia, Impedância bioelétrica, Adolescents, Excesso de peso.

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Introduction

Increasing interest has been observed in studies that investigate body composition at different stages of life [1]. This is mainly due to the epidemic proportions of obesity [2], which has been considered a public health problem [3] and which is related to other chronic non-communicable diseases (NCDs) [4]. Such facts are due to a contemporary lifestyle, composed mainly by the excessive intake of ultra-processed foods and sedentary behaviors [5].

In Brazilian adults, more than 50% are overweight and 18.9% are obese. It should be noted that in a decade (2006-2016), overweight increased by 26.3% and obesity by 60% [6]. When analyzing cases of overweight and obesity in adolescence, the National School Health Survey (PeNSE) revealed that 23.7% and 7.8% of Brazilian students, between 13 and 17 years old, were overweight and obese, respectively [7]. These data are of concern, especially due to the tendency of these prevalences to remain during adulthood [8]. Furthermore, if current trends continue, estimates point to a higher number of children and adolescents with obesity than with moderate and severe malnutrition by 2022 [9].

Given the worrying prevalence of overweight in the pediatric population, the assessment of body composition is fundamental, mainly, based on valid and reliable techniques that estimate body fat. Traditionally, body fat measurement techniques can be classified as direct, indirect and doubly indirect [10]. Among the indirect techniques, Dual Energy X-Ray Absorptiometry (DXA) and air-displacement plethysmography (ADP) stand out [11]. These methods are accurate, but have a high cost, in addition to requiring trained personnel to carry out the measures, limiting their use in epidemiological studies [12].

Thus, it is interesting to have simpler, faster and less costly methods, which make it possible to carry out studies with such quality observed by doubly indirect methods. In this case, bioelectrical impedance (BIA), considered one of these techniques, becomes an important tool for assessing and monitoring body fat for healthcare professionals. Therefore, this technique should be used from the validation with reference criteria [13].

Even with the practicality of BIA to other means of more accurate assessment of body fat, the validation results are controversial, especially because different BIA devices are being marketed. A previous study, conducted in children, when comparing the values of body fat estimated by BIA (TANITA SC-240) and ADP, revealed an underestimation of the values estimated by BIA to those of ADP [14]. In French adolescents, BIA (Tanita MC-780) overestimated body fat values [15]. On the other hand, in American children and adolescents, it was noted that BIA (TANITA SC-240) presented acceptable precision for estimating body fat when compared to DXA [16].

No studies were found in the literature that evaluated the validity of the BIA scale, model OMRON-514C, with ADP and for this to be possible, the accuracy of BIA must be determined. Therefore, the present study aimed to verify the validity of a commercial BIA scale (OMRON-514C) for the estimation of body fat in Brazilian adolescents, using ADP as a reference criterion.

Methods

Study participants

This is a cross-sectional observational study, linked to a macro project entitled "Bone mineral density in adolescents: what is the relationship with body fat, phy-

sical activity, and sedentary behavior?", carried out in a public elementary school in São José, SC , Brazil, selected intentionally. The research was approved by the Human Research Ethics Committee (opinion No. 1,468,045/2016).

Adolescents with ages between 10.0 and 14.9 years, who were overweight, regularly enrolled in elementary school, who accepted to participate voluntarily in the research with the signature of the term of consent and that the parents or guardians signed the Term of Free and Informed Consent (ICF), were considered eligible for this study.

The following exclusion criteria have been used: 1) inability to stand and/or move; 2) full speech and/or hearing disability; 3) refer to diseases that alter body composition, such as malignant neoplasms, chromosomal changes, paralysis, renal or liver failure, hyper or hypothyroidism; 4) pregnancy; and 5) use of diuretic medications.

The sampling procedure took place by saturation, and all adolescents within the pre-established age group were invited to participate in the research. From an initial sample of 1002 subjects, 433 were excluded for being underweight or obese, 440 refused to participate in the study and 11 were excluded due to the exclusion criteria, totaling 118 adolescents. Of these, 44 were overweighed and have been included in the present study. A posteriori sample power calculation was performed considering the comparison of the mean values and standard deviation of body fat assessed by BIA (17.1 ± 6.6) and ADP (14.2 ± 5.4) and the correlation ($r = 0.497$). An effect size of 0.47 was found with a significance level of 0.05, with a beta value of 0.87.

Variables

The measurement of body mass and height, following standardized procedures [17], of all students was performed by a trained evaluator. Body mass (kg) was measured using a portable digital scale from Tanita (BF683W, Arlington Heigths USA). Height (m) was measured using a stadiometer (Altura Exata, Minas Gerais, Brazil). With these data, the Body Mass Index (BMI) was calculated and classified according to Age-and Sex-specific cutoff points [18].

The assessment of body fat measurements were carried out at the Anthropometry Laboratory of the Federal University of Santa Catarina (UFSC) on days previously scheduled with the school and those responsible for the students, always during the morning shift. Transportation for driving school students to UFSC was provided by the State University of Santa Catarina (UDESC). Before the collection date, the guardians of the students were asked to follow some instructions, which were necessary for the evaluations of the students that would be carried out on the following day: a) be fasting for at least ten hours before the exam; b) using appropriate clothing, boys in swim trunks and girls in tops and shorts that are not loose on the body; c) not carrying metal objects attached to the body, such as earrings, necklaces, and piercings; d) not performing physical exercise eight hours before the exams; e) not drinking alcohol forty-eight hours before, and f) not being in the menstrual period.

Body fat was estimated using the air displacement plethysmography (ADP) method (Bodpod, Life Measurements, Concorde, CA, USA), previously calibrated, which is considered a reference for the estimation of body fat [19], and its validity for this measure in adolescents has already been evidenced [20].

For the BIA method, the body control scale was used (OMRON-514C, São Paulo, Brazil), which has a system of eight electrodes (two in each hand and foot) and performs resistance and reactance measurements in each of the segments using electric current at the intensity of 50 kHz (kilohertz) and 500μA (microamperes) throu-

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ghout the body (from arms to feet). For the evaluation of the students, the manufacturer's instructions were used, thus, they should remain in the orthostatic position, with their feet touching the electrodes of the base of the scale, with their knees and back straight looking towards the horizon, keeping the arms horizontal and the hands in contact with the electrodes of the support display unit, with the shoulders flexed forming an angle of 90° to the body and elbows extended.

Statistical analysis

Statistical analyses were conducted using the IBM SPSS Statistics 20 software, with a significance level of 0.05. Data normality was examined using the Shapiro Wilk test. To compare BIA's estimated body fat values with the reference method (ADP), the paired t-test (systematic bias) was used. Pearson's correlation was used to verify possible relationships between the methods and the agreement between the measurements was analyzed using the Bland and Altman plots [21].

Results

Descriptive data of the study participants are shown in Table I. 44 adolescents participated in the study, of which 25 were female, with a mean age of 12.3 (±1.1) years. Higher (p < 0.05) values for a relative (28.6% and 24.6%) and absolute (17.1 kg and 14.2 kg) body fat estimated by the BIA in relation to ADP, respectively, were found.

Table I - Anthropometric characteristics and body fat of overweight adolescents. São José/SC (2016).

Variables	Mean (SD)
Age (years)	12.3 (1.1)
BM (kg)	58.7 (9.6)
Height (cm)	159.2 (9.9)
BMI (kg/m²)	23.0 (1.7)
Relative fat (BIA)	28.6 (8.6)*
Relative fat (ADP)	24.6 (8.3)
Absolute fat (BIA)	17.1 (6.6)*
Absolute fat (ADP)	14.2 (5.4)

SD = standard deviation; BM = body mass; kg: kilograms; BIA = bioelectrical impedance; ADP = air-displacement plethysmography; BMI = body mass index; *p< 0.05 (comparison of average values between BIA and ADP).

There was no correlation between the measures of relative body fat obtained between the two methods (r = 0.185, p = 0.228), however, the measures of absolute body fat were correlated between the methods, showing a weak to moderate correlation (r = 0.497, p = 0.001) (Figure 1). Regarding the male gender, no correlation between the methods was observed, while in the female gender there was a moderate to strong correlation between the relative (r = 0.565, p = 0.003) and absolute (r = 0.753, p = 0.001) measures.
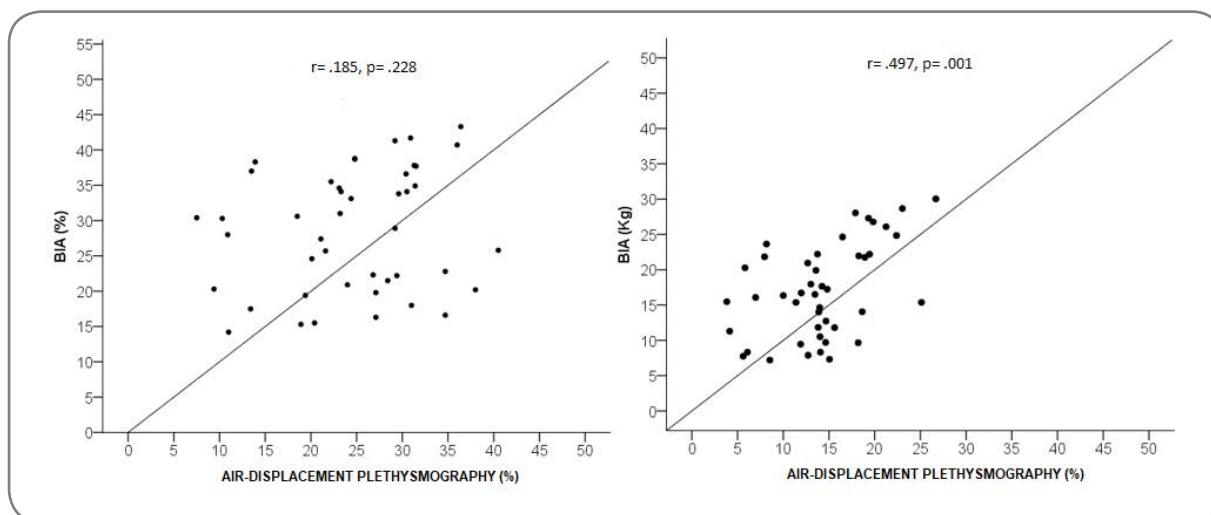
% fat: relative fat; kg: absolute fat.
Figure 1 - Correlation between methods for body composition in overweight adolescents. São José/SC (2016).

Figure 2 shows the analysis of agreement between the relative and absolute body fat measurements obtained by the two methods. A systematic bias was observed for both relative (p = 0.034) and absolute (p = 0.021) body fat measurements, in which, for both measures, the BIA overestimated the measured values, in addition to presenting broad limits of agreement.
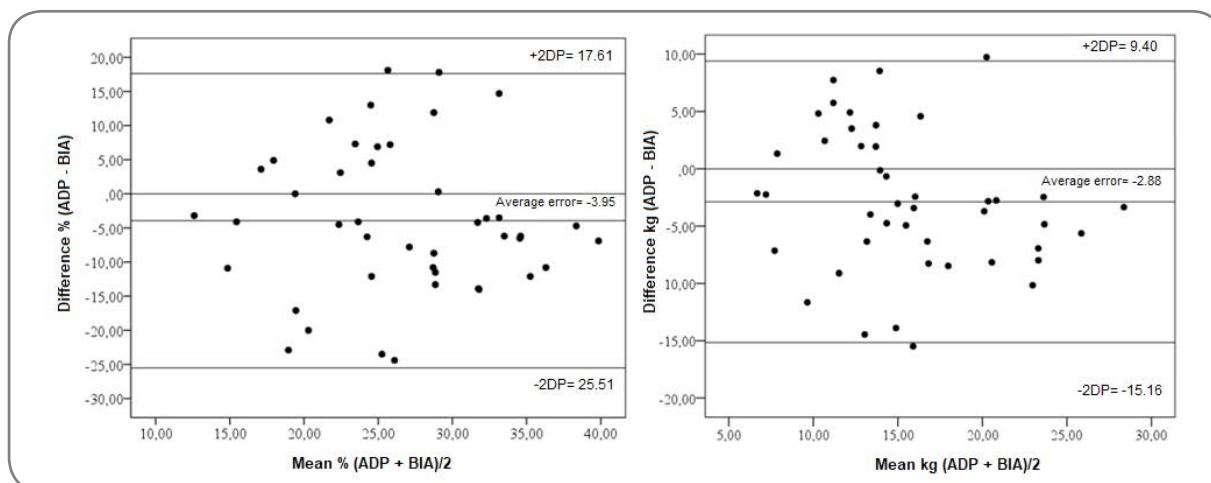

Figure 2 - Difference between body fat (relative and absolute) obtained between bioelectrical impedance and air-displacement plethysmography over their averages.

Discussion

The main result of this study indicated that the values of relative and absolute body fat estimated by BIA OMRON-514c were overestimated in comparison to those of ADP (reference criterion). The existence of numerous brands and models of BIA has been made comparisons between studies difficult, and even those that compared the values obtained by BIA with those of DXA present different results [15,16]. Despite this, Barreira et al. [16], when investigating African-American children, found acceptable accuracy in estimating body fat using BIA Tanita SC-240 and DXA. In a study with Swedish children [14], no significant differences were identified when analyzing BIA Tanita SC-240 and ADP. On the other hand, in a study with French

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adolescents, the body fat values were overestimated by BIA Tanita MC-780 compared to DXA [15]. However, when analyzing two BIA scales (Biodynamics Model 450 and InBody 230) compared to DXA, Faria et al. [22] identified that only BIA InBody230 presented results close to those of DXA, although both models overestimated the values of body fat compared to the reference criterion (DXA).

Researchers verified the validation of methods to estimate body fat in children and adolescents, such as DXA, underwater weighing, skinfold thickness measurement, isotope dilution, dilution of deuterium, and BIA using the 4C model (four compartments) as a reference method [23]. The results demonstrated that BIA generated the least satisfactory results of body fat compared to the other methods investigated [23]. Such results can be explained by the nature of the method that evaluates body water by the resistance to the passage of alternating electric current [24]. Thus, as the amount of body fat increases, there is resistance to electrical conductivity, as the fat mass presents less hydration than lean tissues [24].

It should also be noted that the accuracy of BIA measurements is influenced by factors such as body hydration level, body shape and even ethnicity [25]. For that reason, studies of validation of these instruments would require larger samples. Other studies have also reinforced that the different BIA models available on the market estimate body composition using equations from the manufacturers, with no validity for specific ethnic groups [26,27]. Thus, it is necessary to consider that the BIA model chosen to assess body fat presupposes the knowledge of this information so as not to incur incorrect estimates. For this, a careful analysis of these available data is important in search of more accurate results, to support its use both in epidemiological and clinical practice. However, it should be noted that even generating inaccurate estimates, their results can be valuable, especially in assessments with adolescents who have a high volume of body fat due to difficulties with the use of anthropometry.

The strengths of this study are the use of a homogeneous sample regarding BMI (overweight), as well as the use of a model considered a reference criterion for estimating body fat. Besides, even though studies are comparing the performance of different BIA models with other reference methods for estimating body fat in adolescents, relatively little work has been done to date, which makes these findings important. Among the main limitations of the study, we highlight the lack of knowledge of the BIA ONROM-514c equation for estimating absolute and relative body fat, as well as the small sample size and the heterogeneity of the group to age (10 to 14 years).

Conclusion

The results of this study suggest that body fat estimates are influenced by the use of different assessment methods (ONROM-514c body control scale and ADP). Thus, for overweight adolescents who have similar characteristics to those of the present study, the use of the OMRON-514c scale should be used with caution. In parallel with the use of BIA, the use of another method of estimating body fat in adolescents is recommended to obtain a more accurate assessment of body fat.

Potential conflict of interest
No conflicts of interest with potential potential for this article have been reported.

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Authors' contributions
Conception and design of the research: Pelegrini A, Silva DAS. **Data collection:** Pelegrini A, Silva DAS, Pinto AA, Angelo HCC, Claumann GS. **Analysis and interpretation of data:** Pelegrini A, Pinto AA, Angelo HCC, Claumann GS. **Statistical analysis:** Pelegrini A, Pinto AA. **Obtaining financing:** Pelegrini A. **Writing of the manuscript:** Pelegrini A, Pinto AA, Angelo HCC, Glaumann GS, Silva DAS, Bim MA. **Critical review of the manuscript for important intellectual content:** Pelegrini A, Pinto AA, Angelo HCC, Claumann GS, Silva DAS, Bim MA.

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