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Applicability of the body adiposity index to estimate body fat in adolescents with type-1 diabetes mellitus

Aplicabilidade do índice de adiposidade corporal na estimativa do percentual de gordura de adolescentes com diabetes mellitus tipo 1

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Abstract – The aim of the present study was to verify the level of concordance between Body Adiposity Index (BAI) and *Dual-energy X-ray Absorptiometry* (DEXA) in the evaluation of body fat percentage in adolescents with type-1 diabetes mellitus (DM1). The sample consisted of 34 adolescents (16 boys and 18 girls) aged 10-15 years. Height and hip circumference data were collected for BAI calculation, and fat percentage was evaluated using DEXA. The Shapiro Wilk test was used to verify data normality. The Wilcoxon test was performed to compare age, anthropometric and BMI, BAI z score and DEXA between sexes. The correlation of variables (BAI *vs* DEXA) was evaluated by the Spearman correlation coefficient. For the analysis of residual scores, the Bland-Altman test was applied. The Kappa coefficient (k) was performed to assess the level of concordance between BAI and DEXA. Therefore, weak and non-significant correlation between BAI and DEXA in boys (r= 0.19, p= 0.46), and girls (r= 0.10, p= 0.73) was observed. Thus, weak concordance was observed (k= 0.09) for both sexes. It was concluded that BAI is not recommended to estimate fat percentage in adolescents with DM1.

Key words: Adolescents; Body composition; Diabetes mellitus.

Resumo – *O objetivo do presente estudo foi verificar o nível de concordância entre o Absortometria de Raio-x de Dupla Energia (DEXA) na avaliação do percentual de gordura de adolescentes com diabetes mellitus tipo 1 (DM1). A amostra foi constituída por 34 adolescentes (16 meninos e 18 meninas) com idades entre 10 e 15 anos. Coletaram-se os dados de estatura e circunferência do quadril para cálculo do IAC, bem como avaliação do percentual de gordura via DEXA. O teste de Shapiro Wilk foi utilizado para verificar a normalidade dos dados. O teste de Wilcoxon foi realizado para comparar as variáveis de idade, antropométricas e IMC score Z, IAC e DEXA entre sexos. A correlação das variáveis (IAC vs DEXA) foi avaliada pelo coeficiente de correlação de Spearman. Para análise dos escores residuais aplicou-se o teste de Bland-Altman. O coeficiente de Kappa (k) foi realizado para avaliar o nível de concordância entre o IAC e DEXA. Sendo assim, foi encontrada correlação fraca e não significante entre IAC e DEXA tanto nos meninos (r=0,19; p=0,46), quanto nas meninas (r=0,10; p=0,73). Dessa forma, foi possível perceber concordância fraca (k= 0,09) para ambos os sexos. Conclui-se que o IAC não é recomendado para estimar percentual de gordura em adolescentes com DM1.*

Palavras-chave: *Adolescentes; Composição corporal; Diabetes mellitus.*

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INTRODUCTION

Type-1 diabetes mellitus (DM1) is a chronic disease characterized by the partial or total destruction of beta (β) cells in the pancreas, which results in a defect in the production and / or action of insulin, contributing to metabolic imbalances[1,2]. It is one of the most prevalent chronic diseases in childhood, with a conspicuous risk factor for cardiovascular diseases[3]. The incidence of DM1 has been increasing steadily throughout the world. In Brazil, according to regional studies, the incidence ranges from 7.6 to 12 individual per 100,000 inhabitants[4,5].

Great progress in DM1 therapy has been achieved in recent years. Intensive insulin therapy has improved blood glucose control and reduced the development of vascular complications. However, insulin itself, when used in excess, promotes weight gain which, in turn, increases cardiovascular risk[6]. In addition, some authors have reported that the risk for developing micro and macrovascular complications in patients with DM1 is increased for overweight or obese individuals[7]. Therefore, it is important to identify the presence of risk factors related to body composition in the population with DM1.

Complex and sophisticated techniques that require expensive and non-portable equipment such as DEXA (Dual-energy X-ray Absorptiometry) are available as methods for body composition analysis by estimating body fat percentage (%BF). DEXA is commonly used to measure bone mineral density, but the test also evaluates body composition, determining the amount of fat and lean mass[8]. However, the use of DEXA in patients with DM1 is not always possible in clinical practice or research due to its high cost and complexity of use.

An alternative is the use of anthropometric measures inserted in formulas that can estimate %BF. Anthropometry has been referenced as a good alternative to evaluate nutritional status due to the ease of obtaining measurements, which can be valid and reliable if there is adequate training and measurements are standardized[9].

Taking these factors into account, a 2011 study suggests a new way of assessing body adiposity, called Body Adiposity Index (BAI), which is calculated from height and hip circumference measurements. BAI was developed to simplify fat mass estimation and was therefore based on DEXA[10].

BAI validation in different populations and with different body fat distribution patterns has been recommended in literature[11]. Due to the lack of BAI validation studies for Brazilian adolescents with DM1, the aim of this study was to verify the level of concordance between BAI and DEXA in Brazilian adolescents with DM1.

METHOD

Sample

The present study was carried out with 34 adolescents with DM1 (16 boys and 18 girls) aged 10-15 years attending the Pediatric Endocrinology Unit of the Hospital of Clinics, Curitiba, Brazil, all of whom had been diagnosed with DM1 for more than six months.

Ethical aspects

Participants and parents / guardians signed the Consent Form and the Free and Informed Consent Form, according to a research project approved by the Ethics Committee for Research with Humans of the Hospital of Clinics, Curitiba (protocol No. 1.101.601 - CAEE: 44193214.7 .0000.0096).

Inclusion, Non-Inclusion and Exclusion Criteria

Inclusion criteria were: age between 10 and 15 years and clinical diagnosis of DM1 for more than six months. Patients who did not agree to participate in the study were not included; on the other hand, those with any condition that might affect growth (celiac disease, uncontrolled thyroid disease, growth hormone deficiency, chromosomal abnormalities or other chronic diseases) were excluded.

Anthropometric Measurements and DEXA

Height was measured with accuracy of 0.1 cm with metal stadiometer (Welmy®, Brazil), with participants barefoot, arms along the body and head in the horizontal plane of Frankfurt. Body mass measurement was performed on a scale (Welmy®, Brazil), with accuracy of 0.1 kg. Hip circumference (HC) was measured at the greatest measure around the buttocks with tape horizontally and parallel to the ground, using an inelastic tape measure (Sanny®, Brazil) with accuracy of 0.1 cm[12].

BAI was calculated by dividing HC (cm) by height (m), multiplied by the square root of height (m), and subtracting 18 from the final result[10]. For BAI classification, the classification table proposed by Bergman et al [10] was used as reference.

Body fat percentage (%BF) obtained by means of DEXA (% FDEXA) was determined using the Discovery equipment (Hologic®, USA) with radiation emission of 5μSv. It is a procedure of mapping the different body constituents in which body composition quantification is determined by the attenuation of X-ray in the passage through the various body tissues[13]. Overweight and obesity classification by bone densitometry followed recommendations of Lohman[14] (overweight / obese ≥ 25% of body fat).

Statistical analysis

The Shapiro Wilk test was used to verify data normality. Statistical analysis included descriptive analysis of variables (mean, standard deviation and frequency percentage). The Student's t test was performed to compare age, anthropometric, BMI z score, BAI and DEXA between boys and girls. Correlation between variables (BAI vs DEXA) was evaluated by the Pearson correlation coefficient, together with its respective confidence interval (CI). To analyze residual scores, the Bland-Altman test was applied. The

Kappa coefficient (k) was used to evaluate the level of concordance between BAI and DEXA. Significance level of $p < 0.05$ was adopted. Data analysis was performed using SPSS for Windows, version 22.

RESULTS

Table 1 presents data of age, anthropometric, BMI z score, BAI and DEXA of adolescents evaluated for sample characterization. Thus, a significant difference in body fat can be observed through DEXA, in which girls present higher fat percentage in relation to boys. In the other variables, no significant values were observed.

Table 1. Sample characterization

Variables	Boys (n=16)	Girls (n=18)	t	p
Age (years)	13.22±2.01	13.22±2.03	0.491	0.313
Body Mass (kg)	46.03±13.66	48.94±12.97	-0.700	0.244
Height (cm)	153.4±15.59	153.7±10.8	0.008	0.496
Hip Circumference (HC)	0.97±0.16	0.96±0.15	0.040	0.484
BMI z score (kg/m^2)	0.16±0.84	0.55±0.87	-1.306	0.100
BAI (%BF)	24.14±4.44	22.74±3.66	0.274	0.393
DEXA (%FDEXA)	16.20±5.65	31.82±9.30	-6.627	0.001

Note. BAI - body adiposity index; DEXA - Dual Energy X-Ray Absorptiometry.

Table 2 presents the classifications obtained through BAI and DEXA evaluation protocols. According to BAI, a large proportion of boys are overweight. Girls are considered with normal weight. When values obtained by DEXA are considered, the majority of boys are considered with normal weight, whereas most girls are considered obese.

Table 2. Body fat classification through the BAI and DEXA protocols

	Boys (n=16)		Girls (n=18)	
Category	BAI (%BF)	DEXA (%BF)	BAI (%BF)	DEXA (%BF)
Normal weight	(n=4) 25%	(n=12) 55%	(n=10) 100%	(n=5) 28%
Overweight	(n=7) 44%	(n=4) 25%	---	(n=3) 16%
Obesity	(n=5) 31%	---	---	(n=10) 56%

Note. * For DEXA, fat percentage over 25% is considered overweight / obesity; ** For BAI: Normal weight (BAI 21 to 32), overweight (BAI 33 to 38) and obesity (BAI above 38).

Figures 1 and 2 show the correlation between BAI and DEXA of boys and girls, and weak and non-significant correlation was observed in both sexes, boys ($r = 0.19$, $p = 0.46$) (95% CI = -0.33 -0.62) and girls ($r = 0.10$, $p = 0.73$) (95% CI = -0.39 -0.53), respectively.

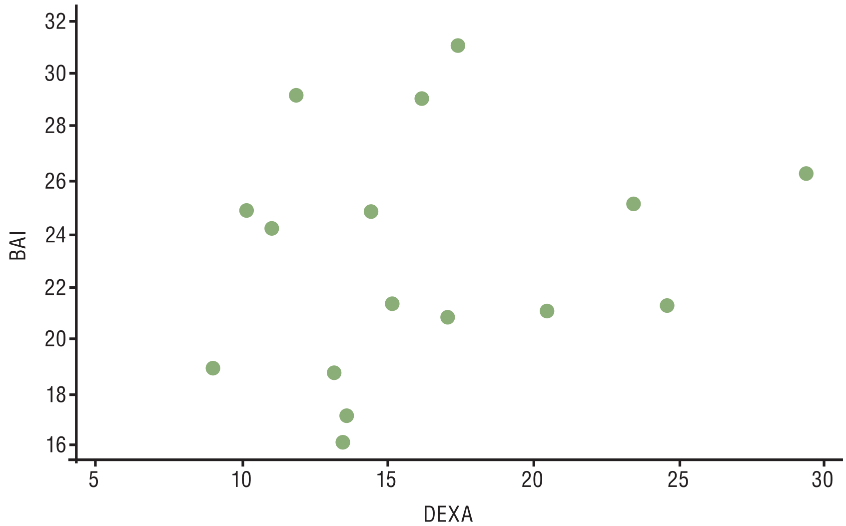

Figure 1. Correlation between BAI and DEXA of boys

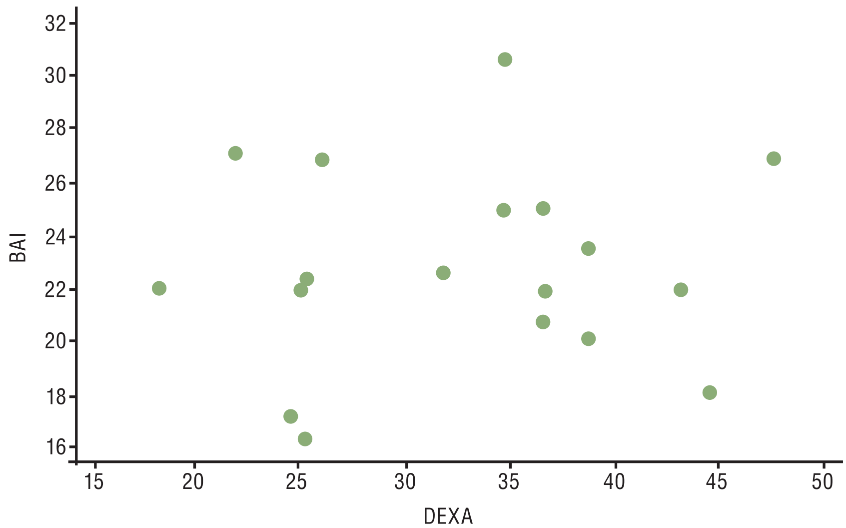

Figure 2. Correlation between BAI and DEXA of girls

Table 3 shows the level of concordance among variables, so it is possible to perceive weak concordance between methods (Kappa = 0.09) [15]. The limits of concordance in the Bland-Altman test were (19.5 to -5.8) for boys and (7.2 to -27.6) for girls.

Table 3. Level of concordance between DEXA and BAI

		DEXA			Total
		Normal weight	Overweight	Obesity	
BAI	Normal weight	9 26.5%	3 8.8%	10 29.4%	22 64.7%
	Overweight	7 20.6%	0 0.0%	0 0,0%	7 20.6%
	Obesity	1 2.9%	4 11.8%	0 0.0%	5 14.7%
Total		17 50.0%	7 20.6%	10 29.4%	34 100.0%

Note. (Kappa = 0.09, p = 0.754).

DISCUSSION

The aim of the present study was to verify the level of concordance between BAI and DEXA in Brazilian adolescents with DM1. However, from the results obtained, it was observed that BAI is not recommended for adolescents with DM1. The Bland-Altman method shows a tendency of BAI to overestimate adiposity in boys and to underestimate adiposity in girls in relation to DEXA (Figures 1 and 2). Therefore, the limits of concordance in the Bland-Altman test were (19.5 to -5.8) for boys and (7.2 to -27.6) for girls.

In the present study, BAI and DEXA did not show significant correlation coefficient in both boys and girls. In addition, BAI showed poor concordance for both sexes[15].

Although BAI has been recommended in some studies as a useful and practical tool to predict body fat percentage (%BF)[10,16], it should be used with caution, since it is inaccurate[17,18]. Gonçalves et al.[16] evaluated 20 individuals aged 19-49 years and found strong correlation (r = 0.816) between BAI and %BF, assessed by skinfolds. Souza et al.[17] used the same method to evaluate body fat in 60 children aged 10-14 years and found low concordance between BAI and %BF. Likewise, Carpio-Rivera et al.[18] found that BAI is not recommended for body fat prediction because it presents low level of concordance with evaluation obtained by DEXA evaluating 199 Costa Rican students with mean age of 18.96 ± 2.6 years.

The accuracy of BAI has been studied among populations without DM1. For example, in people with Down syndrome, weak concordance between BAI and DEXA was found, suggesting an error when estimating %BF[19]. According to these authors, the use of BAI does not present accuracy to estimate %BF in individuals with Down syndrome, which corroborates information for individuals with DM1.

The results of a study comparing BAI and DEXA in female athletes also indicate poor concordance and a tendency of BAI to overestimate body fat in lean subjects[20]. Other authors have shown that BAI underestimated %BF by 7.56% when compared to DEXA in a group of overweight or obese postmenopausal women[11]. In addition, in a group of men and women aged 55-96 years (n = 954), BAI tended to overestimate %BF in subjects who presented less than 15% BF, and underestimated %BF in subjects with 40% or more body fat according to DEXA[21].

BAI appears to be more accurate when body fat values range from 20% to 30%[21]; the present sample was outside this range, and the mean values between boys and girls according to DEXA was 16.20% and 31.82%, respectively. However, the BAI values of this study in individuals with DM1 are similar to those found for individuals without the disease[11,21], that is, BAI has poor concordance, overestimating %BF in leaner individuals and underestimating it in individuals with higher %BF. In the present study, boys (generally with lower BF) had values overestimated by BAI, while girls (generally with higher BF) had values underestimated by BAI.

A possible explanation for the lack of predictive capacity of BAI in some populations may be due to differences in the body profile among different ethnicities, resulting in changes in body fat distribution among participants[22-24]. Moreover, in some populations, weight gain is not associated with increased hip circumference but rather with waist circumference[25]. The original equation for the BAI calculation does not take into account gender, age and waist circumference data[10].

In general, our findings are in agreement with previous studies in which the BAI validity was studied in individuals of both sexes[22-24]. Among females, the present findings are similar to those found in a study with 102 Brazilian women aged 35-83 years, in which %BF estimated by BAI was compared with values obtained by DEXA. The authors report a significant difference in the values obtained by both methods. In addition, the Bland-Altman analysis, as in the present study, showed a tendency for BAI to underestimate %BF in participants with higher values, while overestimating it in those with lower values[22]. Corroborating the present study, these findings suggest that %BF is not recommended for the population under study.

Originally, BAI was developed and validated for the adult population; however, it is considered important to verify its applicability and validity in other populations, since it is a non-invasive and easy-to-use method. Aarbaouie et al.[26] verified the validity of BAI in a sample of 1615 children aged 5-12 years and developed a new index to assess body fat in children. However, the DM1 adolescent population presents different body composition characteristics due to deficiencies in insulin production and / or utilization[1]. Further studies should be carried out in order to verify the validity of existing equations and, if necessary, to develop specific prediction equations for adolescents with DM1.

The present study did not evaluate the sexual maturation status of adolescents, which is a limitation, since the possibility of finding pre-pubescent, pubescent and post-pubescent adolescents has an important influence on anthropometric measures (especially hip perimeter for girls). This issue is also highlighted in a study that compared the predictive capacity of BMI and BAI, and according to the authors, in contrast to BMI, BAI uses hip circumference, which can also be influenced by sex[27].

On the other hand, it is believed that the interest of verifying the applicability of BAI to predict %BF in adolescents with DM1 is a strong point of the present study, since the risk of developing micro and macrovascular complications in patients with DM1 is increased for overweight or obese individuals[7], and a simple and easy-to-use method to aid in the identification of risk factors related to body composition would be of great value for treatment.

CONCLUSION

Body adiposity index is not recommended to estimate %BF in Brazilian adolescents with DM1. However, caution is needed when using prediction equations, as well as any other indirect method to estimate %BF, since they have limitations that may underestimate or overestimate %BF in the population.

COMPLIANCE WITH ETHICAL STANDARDS

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Ethical approval

Ethical approval was obtained from the local Human Research Ethics Committee – General Hospital of Curitiba (No. 1.101.601), and the protocol was written in accordance with standards set by the Declaration of Helsinki.

Conflict of interest statement

The authors have no conflict of interests to declare.

Author Contributions

Conceived and designed the experiments: DBR, NL, SNF, LPGM. Performed the experiments: DBR, WCS, VAL, MF. Analyzed data: ACS, AMR. Contributed with reagents/materials/analysis tools: SNF, LPGM. Wrote the paper: DBR, WCS, SNF, LPGM.

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