**Evaluation of the body adiposity index against dual-energy X-ray absorptiometry for assessing body composition in children and adolescents**

**Running head:** Assessing body composition in children and adolescents

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## ABSTRACT

**Background**: It is important to clarify the association of lean and fat mass between children and adolescents considering the rising prevalence of overweight and obesity in this age group. The aim of this study was to verify the association between the body adiposity index (BAI) and dual energy X-ray absorptiometry (DXA) methods for analyzing body composition, as well as analyzing the validity of BAI to verify the percentage of fat in children and adolescents. **Methods**: The sample was composed of 106 children and adolescents, 44 females (age: 11.5±1.8 years) and 62 evils (13.6±2.6 years). The body fat (%F) was measured using DXA and the doubly indirect BAI body fat estimation technique. **Results**: The BAI and DXA estimates of %F were strongly correlated (Boys: $r=0.71$, $p<0.0001$; Girls: $r=0.72$, $p<0.0001$). The linear regression analyses showed that BAI is significant to estimate the %F in total sample ($p<0.0001$). For boys, the %F analyzes performed by BAI and DXA did not show any differences when compared ($p=0.2$). In addition, BAI pointed out a significant proportion bias for both sexes ($p<0.0001$), which suggests its inefficiency in the analysis of %F. **Conclusions**: BAI and DXA correlate however, there is low reliability and a high proportion bias for the analysis of %F by BAI.



**Key words:** body composition; body adiposity index; DXA; children.

## INTRODUCTION

On a worldwide prevalence scale, in the last decade, approximately 43 million children were identified as overweight or obese and another 92 million identified risks of being overweight (Aguilar-Salinas et al., 2004; Thivel et al., 2009). Body weight information allows you to monitor changes resulting from exercise programs and / or diets administered to improve health or sports performance (Thomas, Burke, & Erdman, 2016). However, the analysis of the variation of human body morphology by body weight alone, may not be the most adequate estimate, it is recommended to check the relative indices of adipose tissue in order to infer whether or not the evaluated subjects are in adequate parameters for body health (Okorodudu et al., 2010, Bergman et al., 2011).

In this context, in order to provide parameters for the measurement of childhood obesity, several anthropometric indicators have been used to identify the risk of body adiposity in children and adolescents (Aguilar-Salinas et al., 2004; Thivel et al., 2009; Nana, Slater, Stwart, & Burke, 2015). Parameters such as the observation of waist and / or hip circumference patterns are commonly used to indicate different degrees of obesity (Taylor et al., 2011; Tybor et al., 2010). However, the isolated observation of these anthropometric parameters has low reliability and is controversial for the measurement of abdominal adiposity in pediatric patients (Anornia et al., 2013). Dual energy X-ray absorptiometry (DXA) is a state-of-the-art technique for assessing body composition (Nana, Slater, Stwart, & Burke, 2015). This technique has advantages in providing reproducible and advanced measurements of body components. It has good accuracy, is widely available and recognized in the scientific literature (Borga et al., 2018).

However, large-scale use is not feasible. In addition to having a high cost, there is also the difficulty of logistics in field evaluations. Therefore, health professionals use the anthropometric technique that is more economical and direct as an alternative to perform daily assessments in clinical practice or in school routine (Wasserman, O'Donnell, & Gordon, 2017). In children and adolescents, some studies have proposed protocols or predictive fat equations using skinfold measurements (Karupaiah, 2018; Wendel et al., 2017). However, the technique of skinfold measurement requires intensive training and attention to a series of factors to avoid erroneous measurements and compromise of the evaluation process. Although these errors can occur because of the diversity of the physical characteristics of the investigated population, the main cause is inter- and intra-rater technical variations (Wendel et al., 2017).

These variability errors include the time interval between measurements or measurement reading time, multiplicity of patterns in the marking of anatomical points (and the standardization of finger opening for clamping), and inconsistency in the handling technique of the adipometer (Machado, 2008). Therefore, researchers have been proposing new anthropometric protocols to solve the burden of technical variations in skinfold measurement. For adults, Bergman et al. (2011) proposed the body adiposity index (BAI), which is composed of straight-forward anthropometric measurements (hip circumference and body height) incorporated into a mathematical equation to estimate relative body composition. Validations of this approach have been either confirmed or disputed in other countries and in Brazil (Lam, Koh, Chen, Wong, & Fallows, 2015; Cerqueira et al., 2018; Bernhard et al., 2017).

BAI is a simple, inexpensive tool for large-scale use, but it remains to be validated in children and adolescents and several studies have suggested further research in this aspect (Freedman et al., 2012; Filgueiras et al., 2018). Thus, there is a need for validation and dissemination of reliable, objective, and easily applicable methods that can be used for young people. However, tools with low financial cost and reliability based on a gold standard are necessary for the analysis of the percentage of fat in the pediatric population (Gonçalves et al., 2014). Therefore, the aim of the present study was to examine the correlation of body composition estimated using BAI and DXA in children and adolescents, as well as the validity of BAI to quantify percentage fat in young children and adolescents aged 7 to 17 years. Thus, the study hypothesized that the body adiposity index can be a useful tool with reliability similar to that of methods such as DXA for verifying the percentage of body fat in children and adolescents.

## MATERIAL AND METHODS

### *Subjects*

This descriptive, quantitative and cross-sectional study included a convenience sample of 106 children and adolescents of both sexes, aged between 7 and 17 years (11.6 ± 2.3 years). Volunteers aged 7 to 17 years were included, however those with musculoskeletal injuries or disability that could compromise the performance of the proposed tests, those not in the required age range, and those who did not provide consent to participate in any stage of the study were excluded.

The research design was reviewed and approved by the Research Ethics Committee, CEP of the Federal University of Rio Grande do Norte (CAEE: 15865619.70000.5537; Opinion: 3.552.010 / 2019), according to Resolution 466/12 of the National Health Council, on December 12,2012, strictly adhering to the international ethical principles of the Declaration of Helsinki, 2012. All volunteers and their respective guardians were informed about the research objectives and the methods to be adopted in the study. Informed consent forms were signed by the volunteers and their respective legal guardians, according to Resolution 466/12 of the Ministry of Health (Brazil). The study complied with all the international requirements and standards of the STROBE checklist for observational studies of incidence and prevalence (Strobe, 2019).

*Procedures*

All participants were authorized by their respective parents to undergo anthropometric and full body densitometry measurements in a single visit to the laboratory of the Department of Physical Education at the Federal University of Rio Grande do Norte (UFRN). All procedures were standardized and conducted by a team of trained health professionals, with at least five years of experience in scientific research. Thus, the team was composed of two evaluators. One was responsible for taking measurements related to perimeters and diameters and the other was responsible for taking skinfold measurements. Also included were a laboratory technician responsible for performing the DXA procedures and a nursing technician responsible for individually explaining the details of self-assessment of sexual maturation (Figure 1).

****INSERT FIGURE 1****

*Anthropometric analysis*

Eleven anthropometric variables were collected, and the measurement protocol followed the recommendations proposed by ISAK (International Society of the Advancement of Kinanthropometry) (Karupaiah, 2018). Body mass was measured using a digital scale with a variation of 0.10 kg (FILIZOLA®, São Paulo, Brazil). Standing height and sitting height were assessed using a stadiometer with an accuracy of 0.01 cm (SANNY®, São Paulo, Brazil). The perimetry of the right biceps, right calf, arm span, hips and waist were measured with an anthropometric tape (SANNY®, São Paulo, Brazil). The bone diameters of the humerus and femur were measured using a caliper (SANNY®, São Paulo, Brazil).

*Evaluation of biological maturation*

Biological maturation was analyzed by two distinct parameters, namely skeletal maturation that refers to the growth of the human skeleton and the closure of the main bone epiphyses, and sexual maturation that is associated with secondary sexual characteristics (i.e., pubic hair, genital growth) (Tanner, 1962; Malina, 2007; Cabral et al., 2016; by Almeida-Neto et al., 2020; Almeida-Neto et al., 2020). In this sense, skeletal maturation was analyzed through bone age, which was verified by the equation proposed by Cabral et al., (2016). The equation is highly reliable compared to the gold standard hand and wrist X-ray method ($r = 0.868$; $r^2 = 0.754$; $p<0.05$) and consists of:

$$\text{Bone age} = -11{,}620 + 7{,}004\,(\text{height}) + 1{,}226 \times D_{sex} + 0.749\,(\text{age}) - 0.068\,(Tr) + 0.214\,(CAC) - 0.588\,(HBD) + 0.388\,(Df)$$

Tr = skinfold triceps; CAC = corrected arm circumference (refers to arm circumference in centimeters) subtracted by triceps skinfold (Tr) value transformed into centimeters; HBD = humerus bone diameter; Df = femur bone diameter; $D_{sex} = 0$ for a male and 1 for a female participant.

To identify the skeletal maturation stage, the subjects were classified as delayed, normal or accelerated. This classification was determined by subtracting the participant's bone age from their chronological age (both in months) (Malina, 2007). In relation to the classification of the state of maturity, values between -1 and + 1 = normal maturation, delayed maturation <- 1, accelerated maturation> +1 (Malina, 2007).

Sexual maturation was analyzed using the self-assessment method proposed by Tanner (1962). The method assesses the development of secondary sexual characteristics, based on the diagnosis of pubic hair and the size of the genitalia for both sexes, and the size of the breasts for female subjects (Taner, 1962). In this assessment, pubertal staging follows a chronology, which can be classified into up to five stages

(Taner, 1962). Each stage identifies the individual's pubertal stage for that moment, according to the description made by Tanner (1962) and represented through photographs. The evaluated subjects observe the photographs and indicate which stage of development they are at. In this sense, they can be classified as: 1 = Pre pubertal, 2 = Pubertal (initial stage), 3 = Pubertal (intermediate stage), 4 = Pubertal (final stage) and 5 = Post pubertal (Tanner, 1962).

*Body composition*

Body composition was assessed using two methods: BAI and DXA. The former makes use of anthropometric measurements to estimate fat percentage (%fat) according to the following equation (Bergman et al., 2011):

(i) $$\text{BAI } (\%) = [(\text{Hip (cm)}) / (\text{Height (m)} * \sqrt{\text{Height (m)}})] - 18$$

The second method was DXA, which is considered one of the gold standard methods for analyzing body composition, it performs the analysis of fat and lean masses through pediatric algorithms implemented in its programming. Participants were individually analyzed by a single evaluator following a standardized protocol, where participants were placed in the supine position on the DXA and were instructed to remain in a static position throughout the procedure (without causing discomfort to the subject). The analysis was performed on average 10 minutes for each participant (Bazzocchi, Ponti, Albisinni, Battista, & Guglielmi, 2016; Saarelainen, Hakulinen, Rikkonen, Koivumaa-Honkanen, & Jurvelin, 2016).

**Statistics**

The sample size was established *a priori* by adopting an effect size of 0.70 (Bergman, et al., 2011), an $\alpha$ value of 0.05, and a $\beta$ value of 0.80. This estimated a minimum sample of 35 subjects for a sample power of 0.88. The margin of possibility of error was 4.87% for the sample size used in the study (n = 106), which is less than 5%. Data normality was verified using the Shapiro–Wilk test and z-score tests for asymmetry and kurtosis (-1.96 to 1.96). Pearson's linear correlation test was performed to verify the existence of an association between body fat percentage as measured by DXA (independent variable) and BAI (dependent variable). The magnitude of the results of each correlation was determined by the scale proposed by Schober, Boer, &

Schwarte, (2018): insignificant: r<0.10; weak: r = 0.10–0.39; moderate: r = 0.40–0.69; strong: r = 0.70-0.89; and very strong: r = 0.90–1.00. Subsequently, regression analysis was performed. The homogeneity of the regression models was tested using the Breush–Pegan test and the assumptions of normality, variance, and independence of the data were not denied. Comparative analyses between groups were performed using the Student-dependent *t* test. The effect size was calculated using the Cohen test (d). The magnitude of the effect size was assessed using the scale suggested by Santo & Daniel (2017): insignificant: <0.19; small: 0.20–0.49; average: 0.50–0.79; large: 0.80–1.29; very large: <1.30, and a 95% confidence interval was calculated.

To measure the reliability between the measurements by the different methods, we calculated intraclass correlation, the magnitudes of which were determined by the scale recommended by Miot (2016): absence: <0; poor: 0–0.19; weak: 0.20–0.39; moderate: 0.30–0.59; substantial: 0.60–0.79; almost complete: ≥0.80. Bland–Altman plotting was performed to verify the dispersion of data within the limits of agreement, as was defined by the differences of the means between the measures of the variables (Bland & Altman, 1986). For the technical error of anthropometric measurements, the following magnitude was used: Acceptable for skinfolds ≤ 5.0%; acceptable for other anthropometric measurements ≤ 1.0% (Perini, Oliveira, Ornellas, & de Oliveira, 2005). All analyses were performed using the R statistical software (version 4.0.1; R Foundation for Statistical Computing®, Vienna, Austria), and a p level of <0.05 was considered statistically significant.

## RESULTS

The study included 106 children and adolescents of both sexes, 44 girls (mean age, 11.5 ± 1.8 years) and 62 boys (13.6 ± 2.6 years) participants. The participants presented an average height of 150 cm and a fat percentage of 28.4%. The two sexes were on average in similar stages of development, as noted by the average biological maturation (Skeletal maturation, Sexual maturation and Pubic hair) (Table 1).

****INSERT TABLE 1****

There was an association between BAI and DXA measurements of %fat, considered moderately positive for the total sample (r = 0.69; $r^2$ = 0.47; p<0, 0001). However this correlation was stronger when the group was separated by sex (Boys: r=

0.71; $r^2 = 0, 50$; $p<0, 0001$; Girls: $r= 0.72$; $r^2=0, 51$; $p<0, 0001$). In addition, the sum of skinfolds also showed a significant relationship with BAI in all analyzed groups ($p<0.0001$). Fat-free mass showed negative correlations in the total sample and in boys ($p<0.05$), while in girls no significant relationship was found ($p = 0.9$) (Table 2).

****INSERT TABLE 2****

Figure 2 reports the results of linear regression for the estimation of the percentage of fat by the Body adiposity Index (BAI). Thus, for the total sample, the linear regression analysis showed positive results from BAI with DXA ($r^2 = 0.489$; $\beta = 0.317$; $p<0, 0001$), similar results were pointed out for male subjects ($r^2 = 0.504$; $\beta = 0.382$; $p<0.0001$) and female ($r^2 = 0.371$; $\beta = 0.274$; $p<0.0001$). Regarding the sum of skin folds, significant data were indicated for the total sample ($r^2 = 0.365$; $\beta = 4.931$; $p<0.0001$), male subjects ($r^2 = 0.282$; $\beta = 4.604$; $p<0.0001$) and for female individuals ($r^2 = 0.371$; $\beta = 0.274$; $p<0.0001$). Regarding fat-free mass, the results showed significant magnitudes for the total sample ($r^2 = 0.059$; $\beta = -0.502$; $p = 0.01$), male group ($r^2 = 0.098$; $\beta = -0.710$; $p = 0.01$) and for the female group ($r^2 = 0.000$; $\beta = -0.020$; $p=0.9$).

****INSERT FIGURE 2****

In the comparisons between the methods used to verify the percentage of fat, the results reported by DXA showed superiority for the female group and for the total sample. While for the male group, no significant differences were found between the methods (Table 3).

****INSERT TABLE 3****

The Bland - Altman analysis showed significant agreement, between the BAI and DXA methods, in relation to boys and the total sample (Figure 3). While for girls sample the limits of agreement were not significant. Table 4 complements the information in Figure 3, showing details about the systematic error identified in BAI's analysis in relation to %fat. Thus, BAI points out significant proportions biases for the analysis of %fat.

****INSERT FIGURE 3****

****INSERT TABLE 4****

The reproducibility analysis revealed that the intraclass association was moderate in the whole group and in the male group. For female group, there was a low intraclass association (Table 5).

****INSERT TABLE 5****

In Table 6, it can be seen that the technical error of measurement (TEM) intra-evaluator was low for the anthropometric measurements performed in this study.

****INSERT TABLE 6****

## DISCUSSION

The objective of this research was to verify the association between BAI and DXA for analysis of percentage body fat, as well as to verify the validity of BAI for the analysis of body composition in children and adolescents. The main findings of the present study were: (i) The analyses carried out by BAI show a significant correlation with those carried out by DXA. As well, they pointed out significant correlations with the sum of the skin folds. (ii) In the group of boys, the percentage of fat analyzed by BAI showed no significant difference when compared to that analyzed by DXA. While for girls, significant differences were found. (iii) BAI pointed out significant levels of reliability for verifying the percentage of fat. However, a significant proportion bias was pointed out for both groups analyzed.

Thus, in the present study, a positive association of BAI with DXA and BAI with the sum of skin folds was observed in all groups analyzed. Corroborating the findings of Carpio-Rivera, Hérnadez-Elizondo, Salicetti-Fonseca, Solera-Herra, & Moncada-Jiménez, 2016), the authors' results indicated positive associations of the percentage of body fat analyzed by BAI and DXA in a sample of young students from Costa Rica. In addition, BAI showed a significant correlation with the percentage of fat measured through skinfold measurements (Ramírez-Vélez, 2017).

However, despite presenting significant associations, it is noteworthy that in the findings of the present study the percentage of fat assessed by BAI showed a statistically significant difference in relation to the analysis of body fat performed by

DXA for the total group and girls. While for boys there were no significant differences between the methods. In this context, it is important to note that the findings of the present research also indicate that the percentage of fat detected by the DXA showed that the female group showed superior values in relation to the male group ($p<0.05$). Therefore, it is possible to highlight that in relation to different levels of fat percentage, BAI presents errors of estimate for subjects with high body adiposity, demonstrating greater sensitivity for the analysis of the fat mass of subjects with lower percentage fat mass (Segheto, Coelho, & Silva, 2017).

Kanehisa, Ikegawa, & Fukunaga (1994) and Zhao & Zhang (2015) evaluated body components in children, observing in their respective studies that the greatest differences in the percentage of fat mass were found in the groups composed of female subjects, similar results in relation to the percentage of fat had already been evidenced by previous studies (El Aarboui et al., 2013; Dobashi, Takahashi, & Nagahra, 2017). Thus, it is important to highlight that among the mechanisms arising during puberty, in female individuals there are variations in biochemical some parameters, which regulate morphological changes and leptin levels (i.e., hormone produced by the body's fat cells and has the function of regulating body through weight appetite), which reflects changes related to the accumulation of fat mass (Alvim et al. , 2014; Newton, Hanks, Davis, & Casazza, 2013). While in male individuals, the mechanisms arising from puberty, favor the elevation of steroidal sex hormones that can favor the gain of muscle mass and the reduction of body fat (Taner, 1962; Cabral et al., 2016; Scheffler & Hermanussen, 2018).

It is important to highlight that, despite the aforementioned divergences arising from puberty, in the present research in relation to reliability, the BAI method showed significant results for the total sample and for boys, while for girls BAI did not demonstrate satisfactory reliability indexes in relation to analysis of adipose body tissue in female children and adolescents.

It was possible to observe that skeletal and sexual maturation did not indicate significant relationships with BAI. It is possible to observe in the literature studies that evaluated the effectiveness of BAI, in relation to the analysis of the percentage of fat in pediatric subjects of both sexes (Freedman et al., 2012; Dias, Ávila, & Damasceno, 2014). The aforementioned authors identified that the BAI concordance indexes were not satisfactory, and subsequently proposed a new mathematical model called BAIp (pediatric body adiposity index) (Freedman et al., 2012). Thus, the authors can state that BAIp may be a marker of overweight and body fat in obese children of both sexes than BAI (Zhao & Zhang, 2015; Rossato et al., 2017).

It was possible to observe that there was a satisfactory level of agreement from BAI in the total sample (ICC: 0.421). In addition, there was a statistically significant difference in the BAI analysis with the DXA analysis ($p<0.0001$) in relation to the total sample. However, for boys, a satisfactory agreement was found (ICC: 0.580) and although no statistically significant differences were found between BAI and DXA analyzes ($p = 0.2$), the analysis of proportion biases in both point groups out that BAI is not an accurate estimator for the percentage of fat, that is, the method has significant error margins. This indicates that the method is not effective in analyzing the body composition of young pediatric patients, which corroborates previous studies, where they did not find significant reliability indexes for BAI in relation to samples composed by subjects of both sexes and in relation to samples composed only of individuals of the same sex (Freedman et al., 2012; Filgueiras et al., 2018).

In view of the approaches, it is noteworthy that among the methodological aspects of the present study, anthropometric analyzes pointed out technical errors below 5% for skinfold measurements and below 1% for other measures. Thus indicating a significant reliability for these analyzes (Perini et. al., 2005). Technical measurement errors below 5% for skin folds and below 1% for other anthropometric measurements indicate that the evaluator is experienced in anthropometric analysis and strengthens the analysis in relation to the collected data (Perini et al., 2005; Da Costa et al., 2019).

The perspective of the present study is to guide health professionals on the peculiarities of using BAI to analyze the percentage of fat in pediatric patients of both sexes, which despite being a low-cost tool is not effective for this population. Therefore, it is encouraged that future research seeks to adjust the BAI so that the method becomes more appropriate for the pediatric population. Thus, despite the relevance of the results, the present study has some limitations: (i) The study was observational in design, which prevents the establishment of a cause and effect relationship in relation to the correlation analyzes. (ii) Biological maturation was analyzed by indirect methods, so that the analysis by the direct method can provide divergent results.

## CONCLUSION

In conclusion, there is a good correlation between body fat index and dual energy X-ray absorptiometry, and poor reliability for the analysis of body fat, however, the method exposes a significant proportion bias, which suggests its ineffectiveness for to estimate the percentage of body fat in young pediatric subjects from 7 to 17 years old and of both sexes.


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## AUTHOR CONTRIBUTIONS

**Tatianny Cesário**: Conceptualization; data curation; formal analysis; writing-original draft. **Paulo Almeida-Neto**: Conceptualization; data curation; formal analysis; writing-review and editing. **Dihogo de Matos**: Conceptualization; writing-review and editing. **Jonathan Wells**: Conceptualization; writing-review and editing. **Felipe Aidar**: Conceptualization; writing-review and editing. **Breno Cabral**: Conceptualization; supervision; writing-review and editing.

**Declaration of Data Availability**: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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**Table 1.** Sample characterization in relation to the characteristics of puberty and body morphology.

| Variables | Total Sample | Boys | Girls |
|---|---|---|---|
| Sample | 106 | 62 | 44 |
| Stature (cm) | 150.6 ± 13.8 | 150 ± 0.15 | 150 ± 0.12 |
| Age (years) | 11.6 ± 2.3 | 13.6 ± 2.6 | 11.5 ± 1.8 |
| Bone age | 12.8 ± 2.55 | 12.2 ± 2.03 | 13.4 ± 3.07 |
| Skeletal Maturation | 0.18 ± 5.33 | -0.17 ± 6.66 | 0.69 ± 2.45 |
| Sexual Maturation | 2.70 ± 1.17 | 2.90 ± 1.21 | 2.59 ± 0.92 |
| Pubic hair (Tanner) | 2.70 ± 1.13 | 2.80 ± 1.25 | 2.54 ± 1.10 |
| Weight (kg) | 41.9 ± 12.3 | 41.5 ± 12.7 | 42.6 ± 11.9 |
| Body Density (g/ml) | 1.10 ± 1.19 | 1.22 ± 1.55* | 0.93 ± 0.12 |
| Lean mass (kg) | 28.2 ± 8.2 | 29.3 ± 9.08 | 26.3 ± 6.77 |
| Fat mass (kg) | 11.4 ± 6.5 | 10.3 ± 5.90* | 14.3 ± 6.80 |
| Fat-free mass (kg) | 30.0 ± 8.11 | 31.3 ± 8.73 | 28.2 ± 6.84 |
| Sum of skin folds (mm) | 63.3 ± 32.1 | 56.0 ± 33.3 | 74.6 ± 27.4* |
| BAI (%fat) | 24.7 ± 3.9 | 23.7 ± 3.85* | 26.1 ± 3.66 |
| DXA (%fat) | 28.4 ± 8.6 | 24.6 ± 7.15* | 33.5 ± 8.12 |

DXA= Dual Energy X-ray Absortometry; BAI = Body adiposity Index; * = Difference between groups. $p<0.05$

**Table 2.** Correlations of study variables with BAI% fat in relation to the total sample and the sample segmented by sex.

| Group | DXA %fat | | | Sum of skin folds (mm) | | | Fat-free mass (kg) | | |
|---|---|---|---|---|---|---|---|---|---|
| | r | $r^2$ | p | r | $r^2$ | p | r | $r^2$ | p |
| Total Sample | 0.69 | 0.47 | <0.0001 | 0.60 | 0.36 | <0.0001 | -0.24 | 0.04 | <0.0001 |
| Boys | 0.71 | 0.50 | <0.0001 | 0.53 | 0.28 | <0.0001 | -0.31 | 0.09 | 0.01 |
| Girls | 0.72 | 0.51 | <0.0001 | 0.64 | 0.40 | <0.0001 | 0.01 | 0.00 | 0.9 |
| | Skeletal Maturation | | | Sexual Maturation | | | Pubic hair (Tanner) | | |
| Total Sample | -0.17 | 0.02 | 0.06 | -0.15 | 0.02 | 0.1 | -0.21 | 0.04 | 0.02 |
| Boys | -0.19 | 0.03 | 0.1 | -0.27 | 0.07 | 0.03 | -0.25 | 0.06 | 0.04 |
| Girls | -0.18 | 0.03 | 0.2 | 0.11 | 0.01 | 0.4 | -0.07 | 0.00 | 0.6 |

r = correlation value; $r^2$ = Value of correlation squared; p - Value = significance value

**Table 3.** Comparisons between BAI and DXA in the total sample and segmented by sex.

| | BAI | DXA | E.S | C.I 95% | S.E BAI | S.E DXA | p - Value |
|---|---|---|---|---|---|---|---|
| Total Sample | 24.7 ± 3.9 | *28.4 ± 8.6 | -0.55 | [-5.56; 1.89] | 0.38 | 0.84 | <0.0001 |
| Boys | 23.7 ± 3.8 | 24.8 ± 7.1 | 0.19 | [-0.16; 0.54] | 0.48 | 0.90 | 0.2 |
| Girls | 26.1 ± 3.6 | *33.5 ± 8.1 | 1.17 | [0.71; 1.63] | 0.55 | 1.22 | <0.001 |

DXA = Dual Energy X-ray Absortometry; BAI = Body adiposity Index; CI = Confidence Interval; ES = Effect Size for the difference between the methods; SE BAI=Standard Error BAI; SE DXA= Standard Error DXA. * Statistically significant difference.

**Table 4.** Analysis of proportion bias of BAI in relation to DXA in the total sample and segmented by sex.

| | Difference size between BAI and DXA | S.E of the Bias of Proportion between BAI and DXA | $r^2$ | β | C.I 95% β | p - Value |
|---|---|---|---|---|---|---|
| Total Sample | 3.73 ± 6.56 | 0.63 | 0.814 | 24.0 | [22.5; 24.5] | <0.0001 |
| Boys | 1.10 ± 5.18 | 0.65 | 0.721 | 23.5 | [23.1; 24.8] | <0.0001 |
| Girls | 7.42 ± 6.56 | 0.99 | 0.799 | 25.3 | [23.6; 26.9] | <0.0001 |

SE =Standard Error; $r^2$ = Value of correlation squared; p - Value = significance value. β = Angular coefficient of linear regression. CI =Confidence Interval.

**Table 5.** BAI coefficient reproducibility for %fat estimation.

| | ICC | CI (95%) | p-Valor |
|---|---|---|---|
| Total Sample | 0.421 | [0.251; 0.565] | <0.0001 |
| Boys | 0.580 | [0.393; 0.726] | <0.0001 |
| Girls | 0.086 | [-0.211; 0.37] | 0.2 |

ICC= Intraclass Correlation Coefficient; CI =Confidence Interval

**Table 6.** Technical measurement error (intra-evaluator)

| Variables | ETM Intra-evaluator (%) |
| --- | --- |
| Arm Perimeter (Cm) | 0.93 |
| Hip Perimeter (Cm) | 0.90 |
| Humerus Diameter (mm) | 0.55 |
| Femur diameter (mm) | 0.57 |
| Height (Cm) | 0.53 |
| Triceps fold (mm) | 2.09 |
| Subscapular fold (mm) | 2.57 |
| Supra-iliac fold (mm) | 3.47 |
| Abdominal Fold (mm) | 4.58 |
| Medial Thigh Fold (mm) | 2.05 |

Intra-evaluator ETM (%) = Technical error of intra-evaluator measurement.

Figure 1

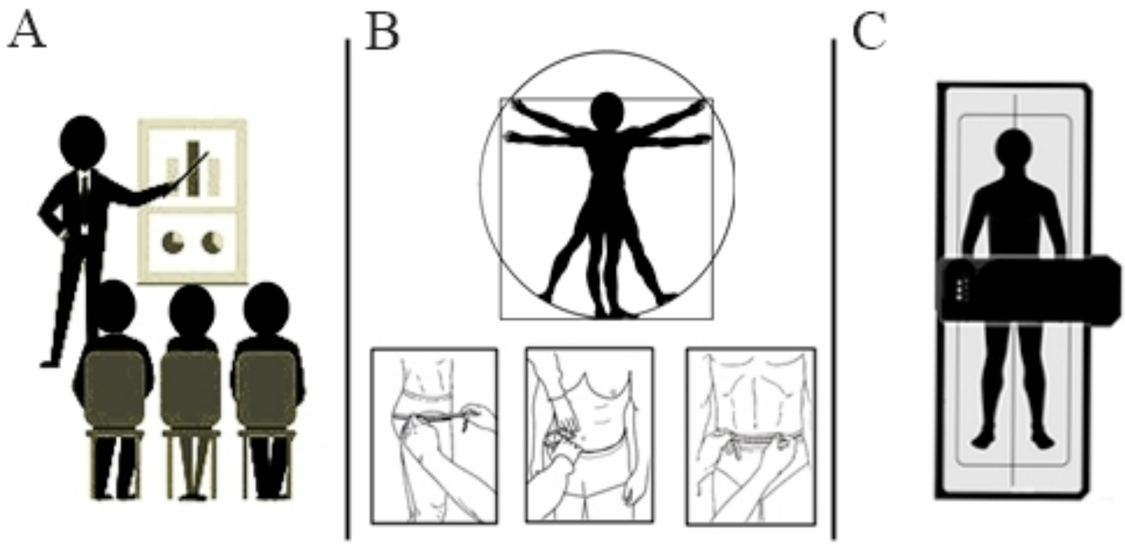
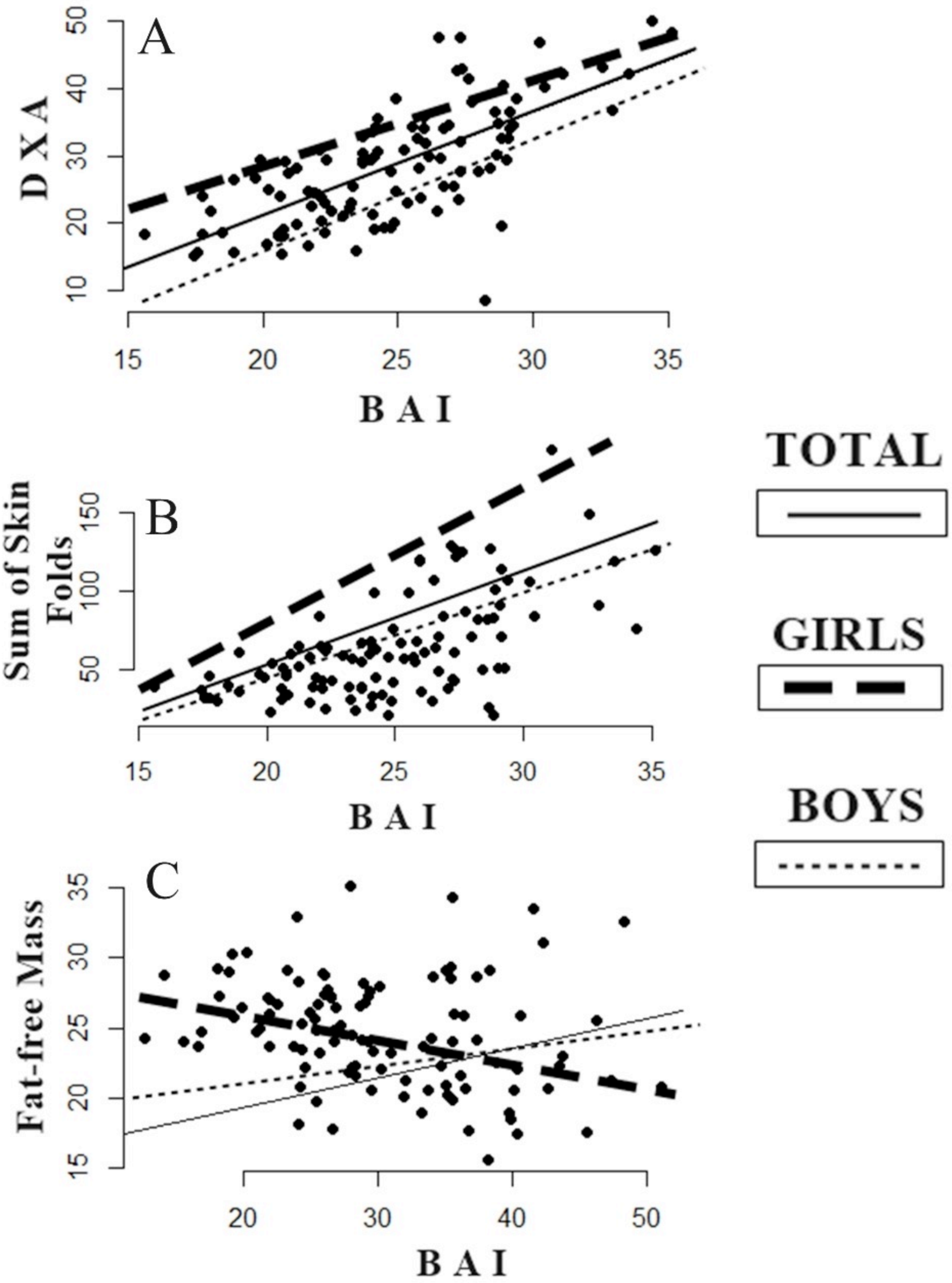
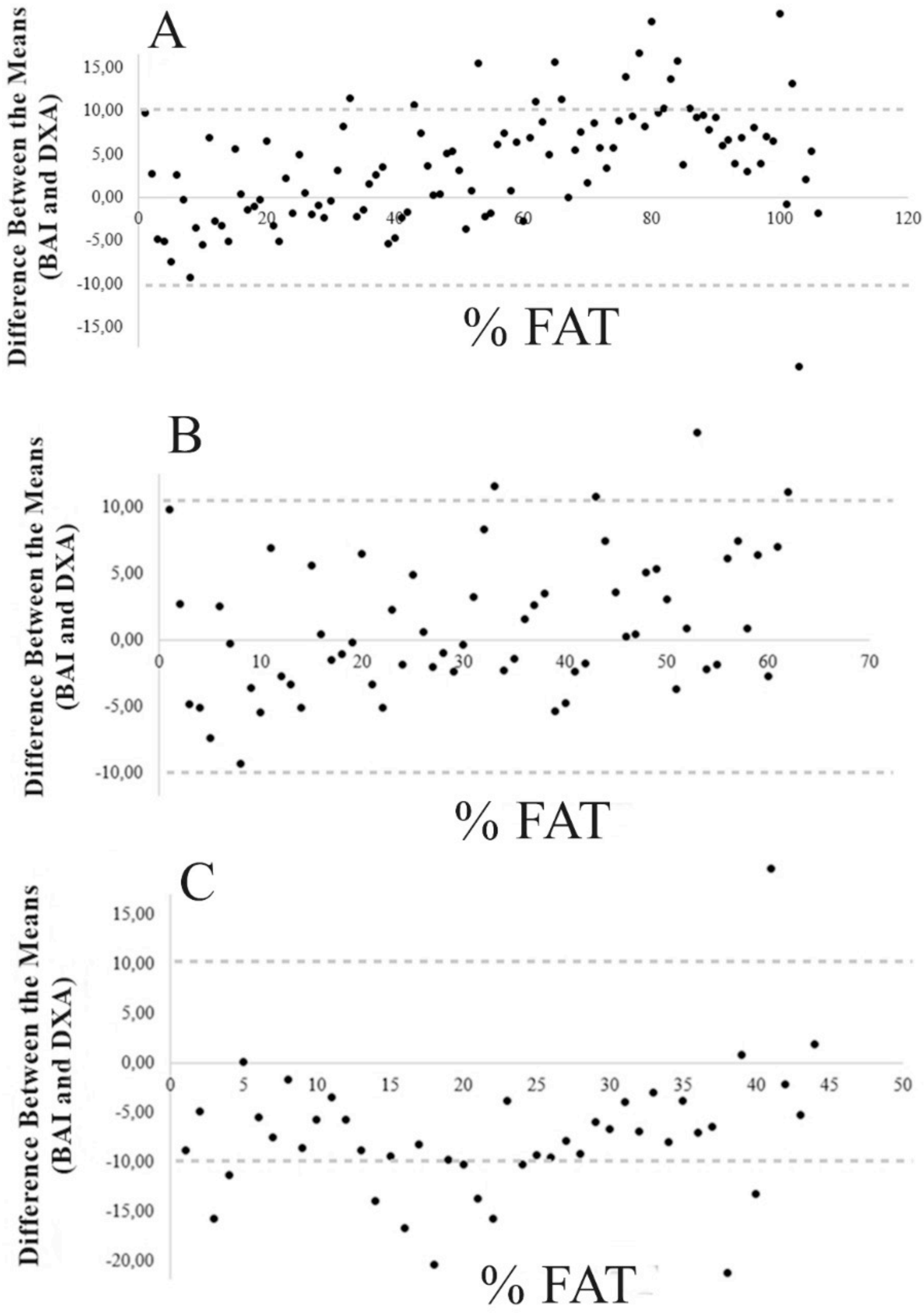


Figure 2.



A
D X A
B A I
B
Sum of Skin Folds
B A I
C
Fat-free Mass
B A I
TOTAL
GIRLS
BOYS

Figure 3


A
Difference Between the Means (BAI and DXA)
15,00
10,00
5,00
0,00
-5,00
-10,00
-15,00
0
20
40
60
80
100
120
% FAT
B
Difference Between the Means (BAI and DXA)
10,00
5,00
0,00
-5,00
-10,00
10
20
30
40
50
60
70
% FAT
C
Difference Between the Means (BAI and DXA)
15,00
10,00
5,00
0,00
-5,00
-10,00
-15,00
-20,00
0
5
10
15
20
25
30
35
40
45
50
% FAT