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Concordance between whole- and half-body scans to evaluate body composition in dual-energy X-ray absorptiometry in children and adolescents with different nutritional and pubertal conditions

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ABSTRACT

Objectives: Evaluation of body composition is a relevant clinical instrument for the follow-up assessments of children and adolescents, and dual-energy X-ray absorptiometry (DXA) is an accurate method for the pediatric population. However, DXA has limited scan area for the obese population. Thus, half-body scans emerged as an alternative to evaluate individuals with obesity. The aim of this study was to compare the body composition of children and adolescents with whole- and half-body DXA scans, considering nutritional status, pubertal development, sex, and age.

Methods: This was a cross-sectional, analytical, and diagnostic intervention study with a sample of 82 participants of both sexes between 4 and 20 y of age. Body composition was evaluated by DXA using an iDXA bone densitometer (GE Healthcare Lunar, Madison, WI, USA). Two evaluations were performed: whole-body and half-body scans. The Bland–Altman correlation and linear regression tests were applied to identify the presence of association bias between the techniques. $\alpha = 0.05$ was set.

Results: Of the 82 participants, 20 were excluded. A high correlation was observed between the data (correlation coefficient ~0.999). Bland–Altman plots and regression analyses demonstrated correlation and randomness bias between whole- and half-body scan techniques in obese or normal weight participants for all DXA markers.

Conclusions: The use of half-body scans was feasible and accurate to evaluate whole-body composition. The difference bias between techniques occurred randomly and was clinically irrelevant. A high correlation was observed between half- and whole-body analysis techniques.

Introduction

Overweight has become one of the major public health problems with epidemic proportions in all age groups in most of the world [1]. The analysis of body composition becomes an essential clinical parameter for the treatment of these patients [2]. Excess of fat is related to the risk for numerous comorbidities, including arterial hypertension, obstructive sleep apnea, insulin resistance, and type 2 diabetes [3].

Among the techniques used for analyzing body composition, dual-energy X-ray absorptiometry (DXA) is an accurate tool with good applicability, especially in pediatric patients [4–6].

Initially, DXA was developed for the analysis of bone mineral density (BMD) and bone mineral content (BMC) [7], and later, its use was expanded to assess body composition [8]. In this way, the examination allows quantification of fat and lean masses and bone densitometry. These measurements are further quantified according to their regional and total distribution.

The use of DXA in hospitals and specialized centers is becoming more frequent. However, its use is still limited because the equipment is not portable [9], and there is a limitation in the scan area

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[10,11], despite the development of more modern equipment with capacity for larger and heavier patients. Considering the importance of body composition assessment among obese individuals, limiting the scan area may restrict the use of DXA. As an alternative, Tataranni and Ravussin [12], described the use of half-body scans for individuals with body measurements that exceeded the DXA scan area. The accuracy of half-body scans supports the use of DXA for a larger range of individuals, allows the comparison of researches that used different techniques (whole- or half-body scans), and enables inclusion of individuals who previously were excluded because their dimensions were beyond the scan area.

Unlike most techniques (bioimpedance, hydrostatic weighing, and skinfolds) that evaluate a two-component model (fat mass and fat-free mass), DXA also assesses BMC. Furthermore, DXA provides the assessment of the regional distribution of body composition [13].

However, some of the limitations of DXA include the size of the scan area and the imaging capabilities [4,13]. With the rise in the prevalence of obesity, the limitation, mainly in the size of the scan area, may be a barrier to the use of DXA in a group of individuals that would benefit from the analysis of body composition.

Initially, the DXA measurement area was 190 cm in length and 60 cm in width, with a weight tolerance of ~115 kg [9]. New equipment can evaluate an area of 228 cm in length, 137 cm in width, and weight of ~280 kg; however, these devices are not commonly used and are not available in all clinical settings. To overcome this limitation, the half-body scan technique was implemented by Tataranni and Ravussin [12], and its use is indicated when body dimensions exceed the scan area. In half-body scans, measurements of two halves of the body are taken, considering anatomic points, rather than the whole-body measurement. The results described by Tataranni and Ravussin demonstrated that the half-body scan technique is accurate in the analysis of body composition, which is confirmed by other studies [14,15].

To our knowledge, there are no studies that examine the accuracy of the half-body scan technique in children and adolescents, considering the nutritional status and developmental phase, owing to possible variations in tissue-density changes with growth and X-ray attenuation. Thus, the analysis of precision and homogeneity of half-body scans can improve the technique applicability in a clinical context. In the study, we examined whether the agreement between half- and whole-body scan analyses would help the homogenization of the method applied to the studies. The whole-body technique was used for participants who fit in the DXA scan area, and when the participants' dimensions exceed those of the scan area, half-body scans were used, or the participants were excluded. Thus, the accuracy of the half-body scan technique, when compared with the whole-body technique, was an alternative to standardized DXA assessment. Considering these aspects, this study aimed to compare body composition of children and adolescents using whole- and half-body DXA scan techniques, considering nutritional status, pubertal development, sex, and age.

Methods

Participants

This was a cross-sectional, analytical study of diagnostic accuracy assessment with a sample of 82 men and women between 4 and 20 y of age. Obese participants were recruited from the Child and Adolescent Obesity Outpatient Clinic of a referral center. Non-obese participants came in spontaneously for DXA assessment after the study had been advertised on social media to promote participation. Obese and non-obese participants were recruited simultaneously.

The participants' height and weight were measured according to nutritional status using the reference values for body mass index (BMI) percentiles from the World Health Organization (WHO) [16]: severely wasted ($P < 0.1$), wasted ($P > 0.1$ and $P < 0.3$), eutrophic ($P \geq 3$ and $P < 85$), overweight ($P \geq 85$ and $P < 97$), obesity ($P \geq 97$ and $P < 99.9$) and severe obesity ($P \geq 99.9$). The sample was also classified by the WHO BMI *Z*-score. In the present study, participants with normal weight, obesity, and severe obesity were included. Participants who were classified as obese and severely obese comprised the obesity group.

The pubertal development was evaluated according to the Tanner's scale: pubic hair and breasts for women; pubic hair and genitalia for men. For statistical analysis, the following pubic hair criterion was used:

- prepubescent: P1
- pubescent: P2 or P3
- postpubescent: P4 or P5

Not all participants reach stage 5 even in adulthood; therefore, individuals with stage 4 development were considered postpubescent.

The study was approved by the ethics committee of the institution. All participants ≥18 y of age and minors' parents or guardians signed an informed consent form; all participants ≥11 y of age signed an informed assent form.

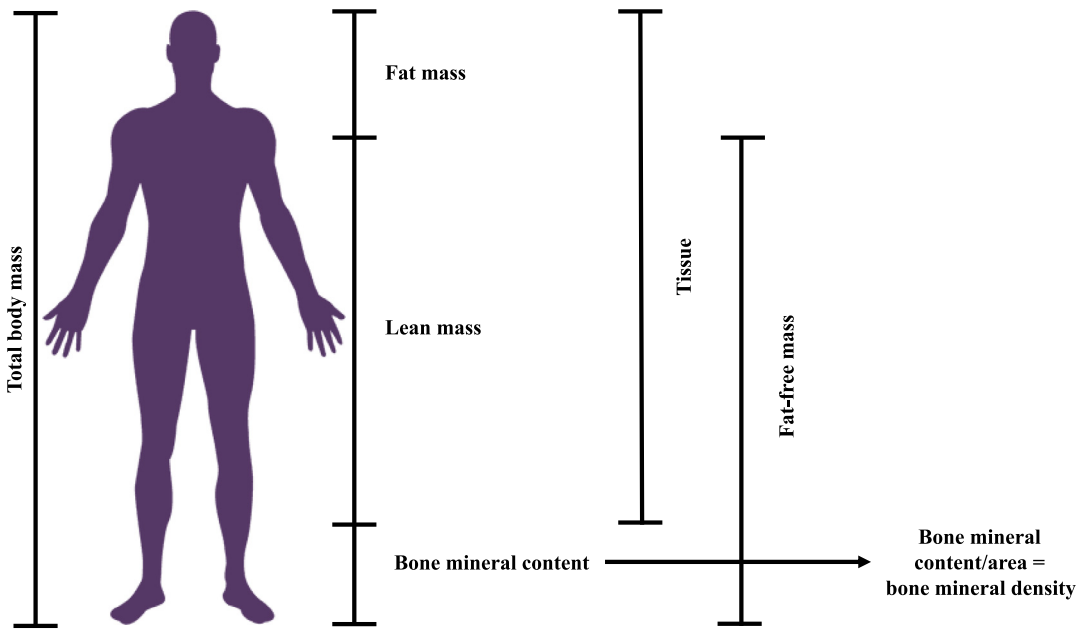

Fig. 1. Schematic representation of the variables analyzed by dual-energy x-ray absorptiometry (DXA).

Participants who dropped out or failed to complete the whole-body assessment owing to the limitations of the equipment dimensions were excluded from the study.

Procedures

The body composition was evaluated by dual-energy X-ray absorptiometry (DXA), using an iDXA bone densitometer (GE Healthcare Lunar, Madison, WI, USA) with fan-beam sensor. After the evaluation, the data were analyzed by the enCore 2011 software version 13.60 (GE Healthcare Lunar). The reliability of the data was ensured by performing the quality assurance test (QA) on a daily basis, and the Bona Fide Phantom was performed on a weekly basis to ensure quality control of the tests.

The acquisition and processing of the images followed the protocol standardized by Hangartner et al. [17]. Adjustments of the regions of interest (ROI) followed the specifications recommended by the manufacturer of the iDXA device.

Two measurements were taken. One evaluated the whole body, in which the participant was placed in the supine position, centralized in the DXA scan table. In the evaluation using the half-body scan technique, participants were placed in dorsal decubitus with the left upper limb positioned outside the scan area. In both techniques, the previously trained operator corrected the position of upper and lower limbs, spine, head, and neck to maintain the best alignment for ROI adjustments.

The individuals were exposed to low dose of radiation, about 100 times less than that of conventional X ray and equivalent to 10% of daily exposure to radiation. The estimated time of each analysis varied according to the tissue thickness and height of the participant.

Participants were instructed to eat a light meal before the test, not to perform physical activities, to wear light clothes, and to remove any metal objects or accessories.

Statistical analysis

In this study, the descriptive analysis was performed using categorical data by absolute and relative frequencies. The numerical data are presented as mean ± SD; median (minimum and maximum values); and 95% confidence interval (CI) for the mean. The normality of the numerical data was evaluated by the following methods:

- analysis of descriptive measures for central tendency;
- probability plots (normal Q-Q plot, Q-Q plot without trend and boxplot); and
- statistical tests (normality tests): Kolmogorov–Smirnov and Shapiro–Wilk.

The association between categorical data was performed using Fisher exact tests and χ^2 test, depending on the distribution of the data in the tables. Simultaneously, the association between the numerical data of independent groups was performed by the following parametric tests:

- *t* test for independent samples (Levene's test was applied to verify the equality of variances): two groups;
- One-way analysis of variance: three groups; and
- non-parametric tests (Mann–Whitney U test for independent samples: two groups; and Kruskall–Wallis test for independent samples; three groups).

Data obtained from the DXA were compared, considering the values obtained from the measurement of the whole-body scan from the data determined by the half-body scan, having as a parameter the right side of the participant. Statistical analyses were performed by *t* tests for paired samples or Wilcoxon-signed tests for related samples according to the distribution of the data in relation to the normality curve. In addition, the Pearson's correlation coefficient or Spearman's rank correlation coefficient (total fat mass and fat percentage) was applied to identify a correlation between both values for the same marker.

In the present study, the linear regression analysis was performed between the differences of the measures (*y* axis = [measure 1 − measure 2]) and the mean of the measures (*x* axis = [measure 1 + measure 2] /2) for the analysis of bias associated with the difference between the data using the Bland–Altman plot, demonstrating the differences between the groups with and without obesity. The whole-body scan data was called measurement 1, and the half-body scan data measurement 2. In the analysis, we considered the variables of total bone mass, total fat mass, total lean mass, total mass, percentage of fat, tissue, fat-free mass, BMD, and BMC. Figure 1 shows a schematic representation of the variables analyzed by DXA.

An additional exploratory analysis was performed comparing the values of body composition variables versus sex, ethnicity, nutritional status, pubertal development, age, height, weight, and BMI. The data is presented according to the *P*-value only.

Finally, the residues were adjusted and compared individually with the markers: sex, ethnicity, pubertal development, weight, height, and BMI. Subsequently, for each of the DXA variables, the residues were evaluated by linear regression for all markers, simultaneously. The residual adjustment was calculated by the following equation

$$\mathrm{Log}_{10}\left[(\text{Difference between measures}^2)/\text{mean between the two measurements}\right].$$

Table 1
Descriptive analysis of the demographic data, nutritional status, and Tanner scale of the participants of the study

Marker	Distribution* (%)
Sex (Female)	36/62 (58.1)
Ethnicity (White)	43/62 (69.4)
Nutritional status (Obesity)	34/62 (54.8)
Tanner Scale	
Prepubescent	16/62 (25.8)
Pubescent	27/62 (43.5)
Postpubescent	19/62 (30.6)
Age (y)†	12.01 ± 4.22; 12.15 (4.28/19.72); 10.94–13.09
Weight (kg)‡	57.55 ± 20.39; 60.45 (17.50/110.70); 52.37–62.73
Height (cm)‡	151.88 ± 18.25; 156.50 (108/181.70); 147.25–156.52
Body mass index (kg/m^2)‡	24.29 ± 6.19; 23.41 (14.69/42.32); 22.72–25.87

*Categorical data presented by means of absolute and relative frequencies. Numerical data presented as: mean ± SD; median (minimum/maximum); 95% confidence interval for the mean.
†Data without normal distribution.
‡Data with normal distribution.

Statistical analyses were performed using the SPSS version 25 (IBM, Armonk, NY, USA) and MedCalc Statistical Software version 16.4.3 (MedCalc Software bvba, Ostend, Belgium;). In all analyses, the α value was set at 0.05. All data from all study participants were obtained using this technique; therefore, no techniques were used to deal with missing data adjustments.

Results

Of the 82 participants originally included in the study, 19 (23.17%) were excluded for failure to meet the body dimension requirements to fit on the scan table (body width ≥ 109.3 cm) to

Table 2
Association between markers with categorical distribution (sex, ethnicity, nutritional status, and Tanner scale)

Sex	White	Non-White	Total	*P*-value
Female	23	13	36	0.403*
Male	20	6	26	
Sex	**Obese**	**Not obese**	**Total**	***P*-value**
Female	26†	10	36	**0.001**‡
Male	8	18	26	
Ethnicity	**Obese**	**Not obese**	**Total**	***P*-value**
White	22	21	43	0.420*
Non-White	12	7	19	
Tanner Scale	**Obese**	**Not obese**	**Total**	***P*-value**
Prepubescent	9	7	16	
Pubescent	16	11	27	0.721‡
Postpubescent	9	10	19	
Tanner Scale	**White**	**Non-White**	**Total**	***P*-value**
Prepubescent	11	5	16	
Pubescent	17	10	27	0.511‡
Postpubescent	15	4	19	
Tanner Scale	**Female**	**Male**	**Total**	***P*-value**
Prepubescent	9	7	16	
Pubescent	17	10	27	0.772‡
Postpubescent	10	9	19	

Significant *P*-values are marked in **bold**. α = 0.05.
*Statistical analysis performed by Fisher Exact Test.
†OR, 5.85; 95% CI, 1.93–17.70 – Taylor series.
‡Statistical analysis performed by the χ^2 test.

Table 3
Association between markers with numerical distribution (weight, height, body mass index, and age) according to the categorical data (sex, ethnicity, nutritional status, and Tanner scale)

Marker	Female	Male	*P*-value	Obese	Not obese	*P*-value
Weight (kg)*	57.72 ± 17.56	57.32 ± 24.14	0.941†	64.53 ± 19.12	49.08 ± 18.88	**0.002**†
Height (cm)*	148.80 ± 14.24	156.15 ± 22.27	0.148†	149.36 ± 14	154.94 ± 22.24	0.256†
BMI (kg/m^2)*	25.62 ± 5.89	22.46 ± 6.23	**0.047**†	28.32 ± 4.86	19.41 ± 3.54	<**0.001**‡
Age (y)§	11.35 (4.28/19.72)	13.15 (4.64/19.28)	0.142	9.94 (5.43/18.05)	14.18 (4.28/19.72)	**0.019**

Marker	White	Non-White	*P*-value
Weight (kg)*	57.03 ± 18.39	57.73 ± 2.85	0.765†
Height (cm)*	153.71 ± 19.14	147.74 ± 15.72	0.791†
BMI (kg/m^2)*	23.62 ± 5.26	25.83 ± 7.84	0.271†
Age (y)§	12.44 (4.28/19.72)	10.76 (5.53/18.05)	0.381

Marker	Prepubescent	Pubescent	Postpubescent	P-value
Weight (kg)‖	35.82 ± 14.17	61.90 ± 17.85	69.67 ± 13.34	< **0.001**†
Height (cm)‖	128.79 ± 10.65	154.67 ± 11.94	167.36 ± 9.44	< **0.001**†
BMI (kg/cm^2)‖	20.98 ± 6.05	25.68 ± 6.05	25.12 ± 5.75	**0.041**‡
Age (y)¶	7.66 (4.28/8.90)	12.03 (7.01/19.72)	16.26 (11.74/19.28)	< **0.001**

BMI, body mass index.
Significant *P*-values are marked in **bold**. α = 0.05.
*Statistical analysis performed by the *t* test for independent samples and data presented as mean ± SD.
†Equal variances assumed for the *t* test for independent samples.
‡Equal variances not assumed for the *t* test for independent samples.
§Statistical analysis performed by the Mann–Whitney U test for independent samples and data presented as median (minimum/maximum).
‖Statistical analysis performed by one-way analysis of variance and data presented as mean ± SD.
¶Statistical analysis performed by the Kruskal–Wallis test for independent samples and data presented as median (minimum/maximum).

allow the comparison between whole- and half-body scans. In addition, one participant was excluded for failure to complete the examination. Thus, the study sample consisted of 62 participants.

Table 1 presents the descriptive data of the sample for sex, nutritional status, ethnicity, pubertal development, age, weight, height, and BMI. Table 2 shows the distribution of the data

Table 4
Association between the values obtained from the measurements using DXA, having as parameters the data obtained from the measurements of the whole-body and the half-body scans

Marker	Group	Distribution*
Total bone mass (g)‖	Whole-body scan	1846.33 ± 670.17; 1832.39 (662.72/3.105,61); 1,676.14–2,016.52
	Half-body scan: right side	1841.52 ± 667.78; 1831.27 (653.78/3,087.11); 1,671.93–2,011.10
P-value		0.103†
Total fat mass (g)§	Whole-body scan	21 336.40 ± 11 443.71; 20 399.39 (4121.56/48 386.77); 18 430.24–24 242.55
	Half-body scan: right side	21 314.53 ± 11 500; 20 426.77 (4156.86/48 323.05); 18 394.08–24 234.99
P-value		0.455‡
Total lean mass (g)‖	Whole-body scan	34 187.72 ± 11 473.68; 33 662.42 (12 037.52/ 59 496.81); 31 273.95–37 101.49
	Half-body scan: right side	34 268.11 ± 11 467.84; 34 223.38 (12 186.62/58 833.36); 31 355.82–37 180.39
P-value		0.086†
Total body mass (kg)‖	Whole-body scan	56.86 ± 20.30; 59.67 (16.97/110.43); 51.70–62.01
	Half-body scan: right side	56.91 ± 20.31; 59.75 (17.07/108.94); 51.75–62.07
P-value		0.266†
Fat percentage (%)§	Whole-body scan	35.98 ± 10.95; 38.56 (12.28/54.23); 33.20–38.76
	Half-body scan: right side	35.87 ± 11.04; 38.49 (12.39/53.81); 33.07–38.67
P-value		0.088‡
Tissue (kg)‖	Whole-body scan	55.52 19.71; 58.83 (16.97/107.88); 50.52–60.53
	Half-body scan: right side	55.58 ± 19.72; 59.05 (17.07/106.44); 50.58–60.59
P-value		0.233†
Fat-free mass (kg)‖	Whole-body scan	35.52 ± 12.14; 35.13 (12.04/62.04); 32.44–38.60
	Half-body scan: right side	35.60 ± 12.13; 35.15 (12.19/61.34); 32.52–38.68
P-value		0.095†
Total bone mineral density (g/cm^2)‖	Whole-body scan	0.97 ± 0.18; 0.98 (0.65/1.39); 0.93–1.02
	Half-body scan: right side	0.98 ± 0.18; 0.98 (0.65/1.40); 0.94–1.03
P-value		<0.001†
Bone mineral content (g)‖	Whole-body scan	1846.81 ± 669.54; 1842.39 (662.72/3.105,61); 1676.77–2016.84
	Half-body scan: right side	1841.04 ± 668.42; 1831.27 (653.78/3.087.11); 1671.30–2010.79
P-value		0.050

DXA, dual-energy x-ray absorptiometry.
α = 0.05.
*Numerical data is presented as: mean ± SD; median (minimum/maximum values); 95% CI for the mean.
†Statistical analysis is performed by the *t* test for paired samples.
‡Statistical analysis is performed by the Wilcoxon-signed test of related samples.
§Data without normal distribution.
‖Data with normal distribution.

according to sex, nutritional status, ethnicity, and pubertal development; and Table 3, according to age, height, weight, and BMI. In this study, the odds ratio was higher for female obesity (5.85; 95% CI, 1.93–17.70). At the same time, obese participants had a lower mean age than participants with normal weight ($P = 0.019$).

The data of the associations between the values of the DXA markers obtained by the whole-body analysis and half-body scan are presented in Table 4. There were no differences between whole- and half-body scan data, except for the following markers of bone densitometry: BMD ($P < 0.001$) and BMC ($P = 0.050$).

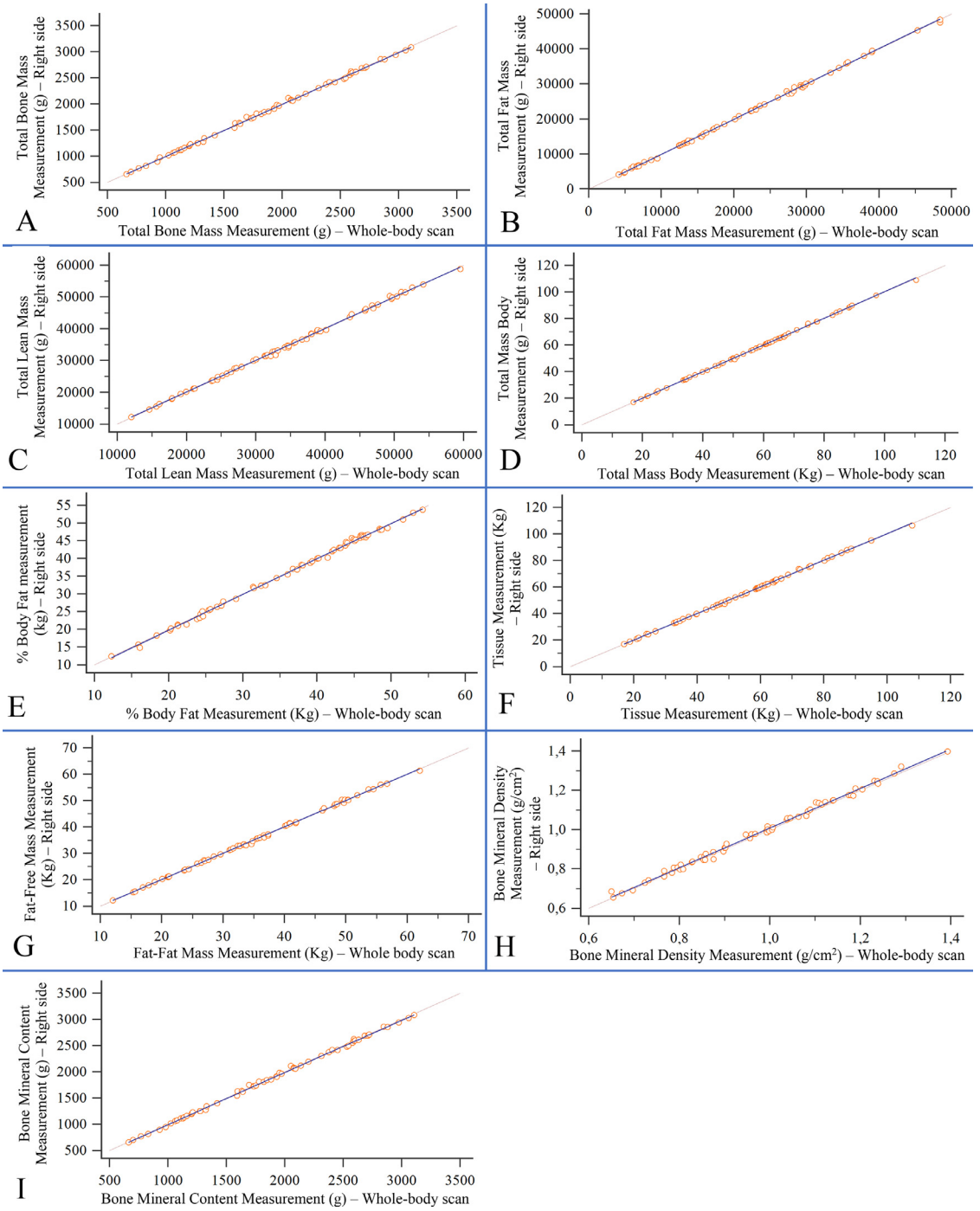

Fig. 2. Correlation between the whole-body scan and the half-body scan. (**A**) Total bone mass: Correlation coefficient r (Rho*) = 0.9994 (95% CI, 0.9990–0.9997; $P < 0.0001$); (**B**) total fat mass: Rho† = 0.9997 (95% CI, 0.9995–0.9998; $P < 0.0001$); (**C**) total lean mass: Rho* = 0.9995 (95% CI, 0.9992–0.9997; $P < 0.0001$); (D) total body mass: Rho* = 0.9998 (95% CI, 0.9997–0.9999; $P < 0.0001$); (**E**) % body mass: Rho† = 0.9992 (95% CI, 0.9986–0.9995; $P < 0.0001$); (**F**) tissue: Rho* = 0.9998 (95% CI, 0.9997–0.9999; $P < 0.0001$); (**G**) fat-free mass: Rho* = 0.9996 (95% CI, 0.9993–0.9997; $P < 0.0001$); (**H**) bone mineral density: Rho* = 0.9976 (95% CI, 0.9960–0.9986; $P < 0.0001$); (**I**) bone mineral density: Rho* = 0.9994 (95% CI, 0.9990–0.9997; $P < 0.0001$). The statistical analysis was done using *Pearson's correlation coefficient and †Spearman's rank correlation coefficient. $\alpha = 0.05$ was adopted in all analyses.

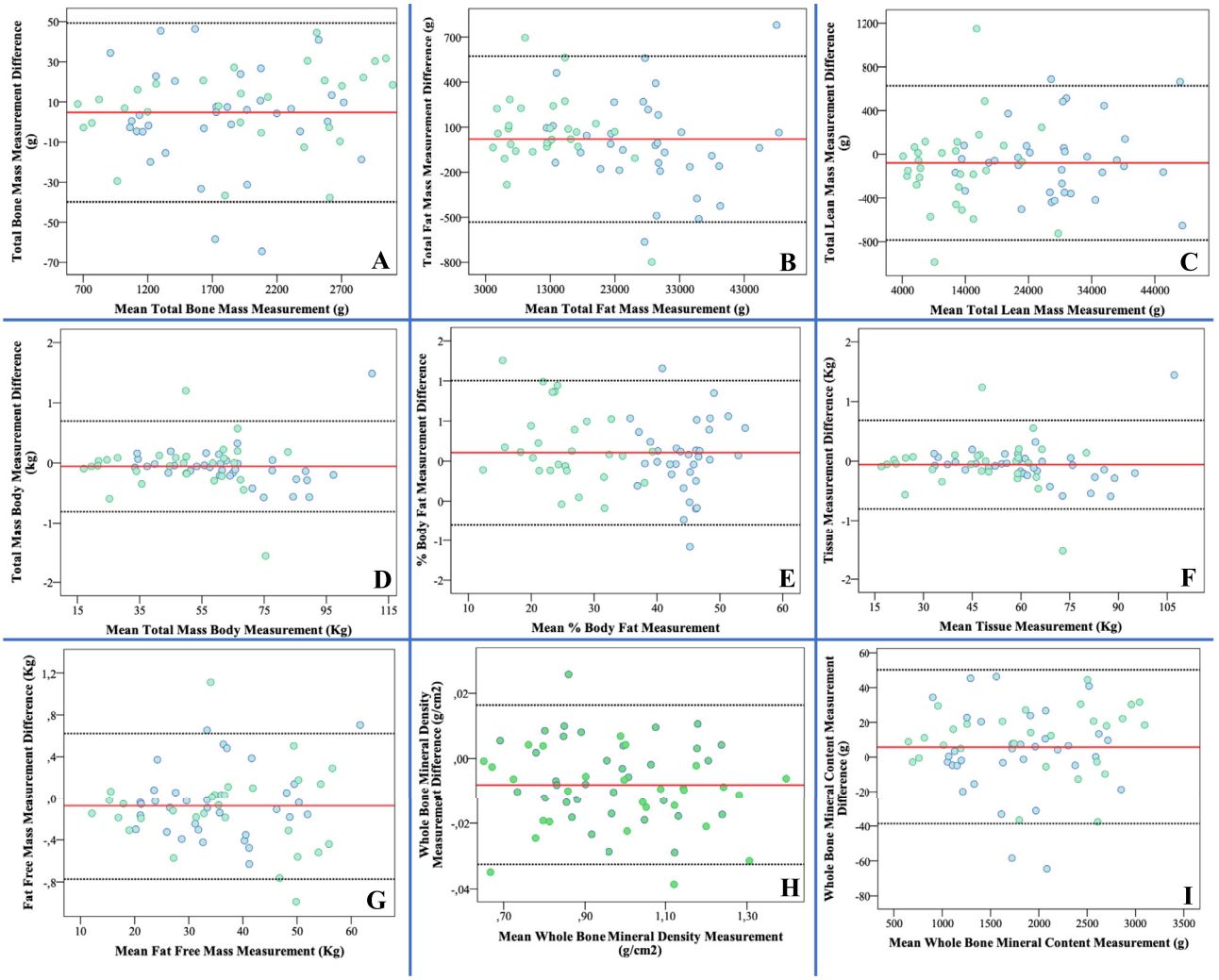

Fig. 3. Bland–Altman plots analyzed from the regression between the whole-body scan and the half-body scan. (**A**) Total bone mass: $R = 0.104$; $R^2 = -0.005$; P-value = 0.418; (**B**) total fat mass: $R = 0.192$; $R^2 = 0.021$; P-value = 0.132; (**C**) total lean mass: $R = 0.016$; $R^2 = 0.016$; P-value = 0.900; (**D**) total body mass: $R = 0.017$; $R^2 = -0.016$; P-value = 0.893; (**E**) % body mass: $R = 0.187$; $R^2 = 0.019$; P-value = 0.142; (**F**) **t**issue: $R = 0.023$; $R^2 = -0.016$; P-value = 0.860; (**G**) **f**at-free mass: $R = 0.023$; $R^2 = -0.016$; P-value = 0.858; (**H**) bone mineral density: $R = 0.132$; $R^2 = 0.002$; P-value = 0.293; (**I**) **b**one mineral content: $R = 0.049$; $R^2 = -0.016$; P-value = 0.703. $\alpha = 0.05$.

For both markers, the difference in the gross values is expressed in decimal values and is possibly a result from a type I error. In addition, to describe the relation between values obtained from the markers (whole- and half-body scans), Pearson's correlation coefficient or Spearman's rank correlation coefficient was applied, and in all cases, a high correlation between the data (correlation coefficient ~0.999; $P < 0.001$) was observed (Fig. 2). Also, the correlation between the values obtained from the DXA measurements of upper limb, lower limb, trunk, android, and gynoid regions is shown in Supplement Table 1, having as parameters the data obtained from the measurements of the whole-body scan and the right side of the half-body scan.

In Figure 3, Bland–Altman plots demonstrate the concordance of whole- and half-body scan analyses, both in obese and normal weight participants, according to the body composition variables. For the bias analysis associated with the difference between the data, the linear regression test between the difference of the measurements (residue) and the mean of the measurements was used, and no significant values ($P > 0.05$) were observed. In this way, the bias between the values was obtained randomly.

The data obtained from the exploratory analysis and the residue data from the comparison between the variables of body composition versus sex, ethnicity, nutritional status, pubertal development, age, height, weight, and BMI are displayed in Table 5. The linear regression data for residues of DXA markers are detailed in Table 6. Only height and age could be used to explain residues for markers of total bone mass and BMC. Tanner scale, weight, sex, ethnicity, and group do not explain the existence of residues.

Discussion

In this study, both DXA techniques demonstrated the same response for body composition analysis. First, numerous clinical conditions lead to changes in weight and height, and health professionals who work with children and adolescents should be alerted to warning signs and make a diagnosis as early as possible.

Special attention should be paid to periods of rapid growth and physical development and to the association between body composition and regulatory mechanisms of the human body [18]. Additionally, the evaluation of body composition is likely to favor the development of new classifications for low weight and obesity. These classifications should be more precise, characterize different metabolic and physiological profiles, and offer better criteria than

Table 5
Association between markers of body composition and residues, with sex, nutritional status, ethnicity, pubertal development, height, weight, body mass index and age of the participants of the study

	Whole-body scan							
Marker	Sex	Nutritional status	Ethnicity	Pubertal development	Height	Weight	BMI	Age
Total bone mass (g)	0.152[*,†]	0.344[*,†]	0.399[†,‡]	**<0.001**[§]	**0.928 (<0.001)**[‖]	**0.769 (<0.001)**[‖]	**0.327 (0.009)**[‖]	**0.917 (<0.001)**[¶]
Total fat mass (g)	**0.020**[#]	**< 0.001**[#]	0.754[#]	**0.007**[**]	**0.257 (0.044)**[¶]	**0.812 (<0.001)**[¶]	**0.947 (<0.001)**[‖]	0.218 (0.088)[¶]
Total lean mass (g)	0.088[*,†]	0.780[*,†]	0.447[*,†]	**<0.001**[§]	**0.925 (<0.001)**[‖]	**0.865 (<0.001)**[‖]	**0.452 (<0.001)**[‖]	**0.869 (<0.001)**[¶]
Total body mass (kg)	0.986[*,†]	**0.003**[*,†]	0.801[*,†]	**< 0.001**[§]	**0.737 (<0.001)**[‖]	**0.999 (<0.001)**[‖]	**0.810 (<0.001)**[‖]	**0.655 (<0.001)**[‖]
Fat percentage (%)	**<0.001**[#]	**<0.001**[#]	0.624[#]	0.162[**]	**−0.282 (0.026)**[¶]	**0.353 (0.005)**[¶]	**0.808 (<0.001)**[¶]	**−0.310 (0.014)**[¶]
Tissue (kg)	0.932[‡, #]	**0.002**[†,‡]	0.774[†,‡]	**< 0.001**[§]	**0.730 (<0.001)**[‖]	**1 (<0.001)**[‖]	**0.818 (<0.001)**[‖]	**0.634 (<0.001)**[¶]
Fat-free mass (kg)	0.085[*,†]	0.789[†,‡]	0.444[†,‡]	**< 0.001**[§]	**0.923 (<0.001)**[‖]	**0.865 (<0.001)**[‖]	**0.454 (<0.001)**[‖]	**0.874 (<0.001)**[¶]
Total bone mineral density (g/cm^2)	0.597[†,‡]	0.621[*,†]	0.785[†,‡]	**< 0.001**[§]	**0.819 (<0.001)**[‖]	**0.739 (<0.001)**[‖]	**0.393 (0.002)**[‖]	**0.866 (<0.001)**[¶]
Bone mineral content (g)	0.149[*,†]	0.535[*,†]	0.404[†,‡]	**< 0.001**[§]	**0.927 (<0.001)**[‖]	**0.768 (<0.001)**[‖]	**0.327 (0.002)**[‖]	**0.917 (<0.001)**[¶]
	Half-body scan: right side							
Marker	Sex	Nutritional status	Ethnicity	Pubertal development	Height	Weight	BMI	Age
Total bone mass (g)	0.163[*,†]	0.360[*,†]	0.372[†,‡]	**< 0.001**[§]	**0.929 (<0.001)**[‖]	**0.769 (<0.001)**[‖]	**0.327 (0.010)**[‖]	**0.915 (<0.001)**[¶]
Total fat mass (g)	**0.018**[#]	**< 0.001**[#]	0.776[#]	**0.006**[**]	**0.261 (0.040)**[¶]	**0.812 (<0.001)**[¶]	**0.943 (<0.001)**[¶]	0.219 (0.087)[¶]
Total lean mass (g)	0.080[*,†]	0.762[†,‡]	0.470[†,‡]	**< 0.001**[§]	**0.925 (<0.001)**[‖]	**0.863 (<0.001)**[‖]	**0.451 (<0.001)**[‖]	**0.867 (<0.001)**[¶]
Total body mass (kg)	0.991[†,‡]	**0.003**[†,‡]	0.803[†,‡]	**< 0.001**[§]	**0.737 (<0.001)**[‖]	**0.999 (<0.001)**[‖]	**0.810 (<0.001)**[‖]	**0.654 (<0.001)**[¶]
Fat percentage (%)	**< 0.001**[#]	**< 0.001**[#]	0.670[#]	0.160[**]	**−0.287 (0.024)**[¶]	**0.345 (0.006)**[¶]	**0.802 (<0.001)**[¶]	**−0.321 (0.011)**[¶]
Tissue (kg)	0.938[†,‡]	**0.002**[†,‡]	0.775[†,‡]	**< 0.001**[§]	**0.729 (<0.001)**[‖]	**1 (<0.001)**[‖]	**0.819 (<0.001)**[‖]	**0.637 (<0.001)**[¶]
Fat-free mass (kg)	0.078[*,†]	0.772[†,‡]	0.465[†,‡]	**< 0.001**[§]	**0.923 (<0.001)**[‖]	**0.863 (<0.001)**[‖]	**0.452 (<0.001)**[‖]	**0.877 (<0.001)**[¶]
Total bone mineral density (g/cm^2)	0.505[†,‡]	0.341[*,†]	0.744[†,‡]	**< 0.001**[§]	**0.824 (<0.001)**[‖]	**0.739 (<0.001)**[‖]	**0.384 (0.002)**[‖]	**0.873 (<0.001)**[¶]
Bone mineral content (g)	0.166[*,†]	0.363[*,†]	0.438[†,‡]	**< 0.001**[§]	**0.929 (<0.001)**[‖]	**0.770 (<0.001)**[‖]	**0.327 (0.002)**[‖]	**0.915 (<0.001)**[¶]
	Residues							
Marker	Sex	Nutritional status	Ethnicity	Pubertal development	Height	Weight	BMI	Age
Total bone mass (g)	0.203[†,‡]	0.265[*,†]	0.991[†,‡]	**0.008**[§]	0.206 (0.108)[‖]	0.080 (0.536)[‖]	−0.058 (0.653)[‖]	0.050 (0.702)[‖]
Total fat mass (g)	0.370[†,‡]	0.900[†,‡]	0.360[†,‡]	0.171[§]	−0.106 (0.412)[‖]	−0.093 (0.473)[‖]	−0.087 (0.500)[‖]	−0.188 (0.143)[‖]
Total lean mass (g)	0.689[†,‡]	0.732[†,‡]	0.560[†,‡]	0.720[§]	0.151 (0.242)[‖]	0.146 (0.258)[‖]	0.079 (0.542)[‖]	0.064 (0.621)[‖]
Total body mass (kg)	0.273[†,‡]	0.789[†,‡]	0.900[†,‡]	0.840[§]	0.060 (0.641)[‖]	0.135 (0.294)[‖]	0.098 (0.559)[‖]	0.067 (0.604)[‖]
Fat percentage (%)	0.302[†,‡]	0.115[†,‡]	0.577[†,‡]	0.178[§]	−0.160 (0.213)[‖]	**−0.292 (0.021)**[‖]	**−0.296 (0.019)**[‖]	−0.240 (0.060)[‖]
Tissue (kg)	0.195[†,‡]	0.882[†,‡]	0.979[†,‡]	0.566[§]	0.107 (0.408)[‖]	0.168 (0.193)[‖]	0.107 (0.409)[‖]	0.119 (0.359)[‖]
Fat-free mass (kg)	0.511[†,‡]	0.503[†,‡]	0.755[†,‡]	0.696[§]	0.173 (0.178)[‖]	0.137 (0.288)[‖]	0.048 (0.713)[‖]	0.085 (0.509)[‖]
Total bone mineral density (g/cm^2)	0.053[†,‡]	0.518[†,‡]	0.489[†,‡]	0.289[§]	−0.001 (0.995)[‖]	0.010 (0.940)[‖]	0.032 (0.807)[‖]	−0.044 (0.733)[‖]
Bone mineral content (g)	0.203[†,‡]	0.266[*,†]	0.990[*,a]	**0.008**[§]	0.206 (0.108)[‖]	0.080 (0.535)[‖]	−0.058 (0.654)[‖]	0.050 (0.701)[‖]

BMI, body mass index.
Significant *P*-values are marked in **bold**. α = 0.05.
[*]Equal variances not assumed for the *t* test for independent samples.
[†]Statistical analysis performed by *t* test for independent samples.
[‡]Equal variances assumed for the *t* test for independent samples.
[§]Statistical analysis performed by one-way analysis of variance.
[‖]Pearson's correlation coefficient (*P*-value).
[¶]Spearman's rank correlation coefficient (*P*-value).
[#]Statistical analysis performed by the Mann–Whitney U test for independent samples.
[**]Statistical analysis performed by the Kruskal–Wallis test for independent samples.

Table 6
Linear regression model for marker residues obtained from the evaluation of body composition using DXA

Variable	*R*	R^2	R^2 adjusted	Constant	Age (y)	Weight (kg)	Height (cm)	Sex	Ethnicity	Tanner scale	Group
Total bone mass (g)	0.511	0.261	0.165	−8.050	−0.247	0.003	0.063	−0.022	0.097	−0.159	0.636
P-value	**0.017**			**< 0.001**	**0.001**	0.832	**0.002**	0.937	0.720	0.561	0.136
Total fat mass (g)	0.344	0.118	0.004	−2.920	−0.098	−0.005	0.031	−0.266	0.313	−0.395	−0.057
P-value	0.418			0.225	0.260	0.766	0.172	0.414	0.328	0.224	0.908
Total lean mass (g)	0.291	0.085	−0.034	−2.912	−0.108	0.012	0.021	0.060	0.149	−0.074	0.480
P-value	0.662			0.161	0.150	0.381	0.269	0.832	0.588	0.791	0.267
Total body mass (kg)	0.243	0.059	−0.063	−0.752	0.066	0.019	−0.030	−0.553	0.019	0.089	−0.050
P-value	0.843			0.819	0.578	0.393	0.331	0.217	0.965	0.840	0.942
Fat percentage (%)	0.438	0.191	0.087	−5.780	−0.147	−0.012	0.350	−0.114	0.232	−0.150	0.403
P-value	0.101			**0.008**	0.060	0.389	0.082	0.694	0.413	0.602	0.365
Tissue (kg)	0.284	0.081	−0.039	−0.618	0.088	0.017	−0.032	−0.586	−0.015	0.137	−0.091
P-value	0.691			0.839	0.427	0.392	0.266	0.160	0.971	0.740	0.886
Fat-free mass (kg)	0.301	0.091	−0.027	−5.870	−0.107	0.011	0.021	0.029	0.091	−0.049	0.505
P-value	0.614			**0.004**	0.135	0.405	0.243	0.914	0.727	0.853	0.217
Total bone mineral density (g/cm^2)	0.306	0.094	−0.024	−3.701	−0.021	0.011	−0.003	−0.350	−0.166	−0.162	0.244
P-value	0.591			**0.043**	0.744	0.339	0.841	0.154	0.488	0.503	0.515
Bone mineral content (g)	0.511	0.261	0.165	−8.051	−0.247	0.003	0.063	−0.022	0.097	−0.159	0.636
P-value	**0.017**			**< 0.001**	**0.001**	0.831	**0.002**	0.938	0.720	0.560	0.136

Significant *P*-values are marked in **bold**. α = 0.05.

those currently available, namely, statistical distribution of BMI values [18].

The epidemic of obesity during childhood and adolescence reinforces the need to learn more about body composition of these individuals who are undergoing intense developmental changes associated to the pathologic condition of obesity.

Wells and Fewtrell [19] elaborated a review on the importance of body composition for pediatric application and described the need for evaluation, mainly in three areas:

1. monitoring body fat, treatment efficacy, and disease evolution;
2. risk assessment; and
3. individualized treatment.

Thus, several techniques that included body composition analysis, such as DXA, may contribute important information for clinical follow-up assessments of children and adolescents.

A variety of techniques are available to evaluate body composition; for instance, simple and inaccurate methods (BMI) or high-precision and high-cost methods (magnetic resonance) [9]. Additionally, in the pediatric population, examination time, low radiation dose, and simple preparation should be factors to be considered to improve acceptance and the success of the examination.

In this context, DXA is a strategic tool: It is a quick and high-precision procedure, uses low doses of radiation, and offers a three-component model (fat mass, lean mass, and bone mass). The practicality and accuracy of DXA have been increasing its application in all age groups, including the population of newborns and young children [5,20–23].

In the literature, the use of half-body scans is reported among the obese adult [15,24] and pediatric populations [14]. In two studies [14,15], the comparison between the whole-body technique and the half-body scan of both right and left sides was evaluated. As in our findings, there was no bias between the techniques, and a perfect correlation was observed between the measurements. In those studies, the markers showing results with significant difference were:

1. Percentage of fat mass: Despite the low magnitude of the half-body scan, it overestimated this variable when compared with the whole-body technique [24]; and
2. Higher BMC in the right side of the half-body scan when compared with the left side [15].

Despite small differences, the authors considered the use of half-body scans in obese population as valid and accurate. In the present study, the analysis of BMD and BMC yielded decimal values of difference when the techniques were compared with each other. The difference was not considered clinically significant.

When DXA is used in research, a bias in the methodology of analysis can be noted:

- The participants who do not fit in the scan area are excluded [14,15]; and
- The literature does not mention the method used for participants whose body dimensions exceed the limits of the scan area [25,26].

In the present literature survey, we did not find any studies that evaluated half-body scans in healthy participants with the aim to standardize the technique for all individuals, regardless of nutritional status, and consequently, to improve the methods described in the articles that used DXA to assess body composition in obese individuals.

The present findings lead to the groundbreaking effort to standardize the method of the studies that use DXA to evaluate body composition in obese patients, and these findings should be applied to other populations. In this study, which included only children and adolescents, for all participants (even those who were excluded because they did not have the suitable whole-body dimensions), only the half-body scan of the arm was needed to fit them in the scan area. In the present study, we found decimals only and no clinically relevant differences for BMD and BMC. In the study by Rothney et al. [15], this difference was justified by the higher prevalence of the dominant right side. Additionally, the half-body scan of the trunk could generate greater bias in the analysis owing to anatomic elements (stomach, pancreas, and larger portion of the heart on the left side of the body; liver, gallbladder, and thicker and broader lungs on the right side of the body) that could unbalance the comparison between whole-body techniques and half-body scans. Importantly, this bias could not be observed in this study.

Limitations

The present study had some limitations. The number of participants included may have been insufficient to yield significant differences between the techniques; however, it is a larger sample than in most studies that compare both techniques. The number of studies was reduced and did not allow comparison of our findings with data from the literature. Some of the published studies do not mention the criteria of body composition analysis when the body dimensions exceeded the DXA scan area. The analysis of covariance to determine the residue does not show adequate statistical power, being an exploratory analysis.

Conclusion

The use of the half-body scan technique studied here is feasible, accurate, and sensitive to determine the values of whole-body composition. The difference bias between techniques occurred randomly and was clinically irrelevant. A high correlation was observed between half-body scans and whole-body analysis techniques.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.nut.2019.03.018.

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