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## Original article

# Are traditional body fat equations and anthropometry valid to estimate body fat in children and adolescents living with HIV?



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### ABSTRACT

The aim of this study was to assess the validity of traditional anthropometric equations and to develop predictive equations of total body and trunk fat for children and adolescents living with HIV based on anthropometric measurements. Forty-eight children and adolescents of both sexes (24 boys) aged 7–17 years, living in Santa Catarina, Brazil, participated in the study. Dual-energy X-ray absorptiometry was used as the reference method to evaluate total body and trunk fat. Height, body weight, circumferences and triceps, subscapular, abdominal and calf skinfolds were measured. The traditional equations of Lohman and Slaughter were used to estimate body fat. Multiple regression models were fitted to predict total body fat (Model 1) and trunk fat (Model 2) using a backward selection procedure. Model 1 had an  $R^2 = 0.85$  and a standard error of the estimate of 1.43. Model 2 had an  $R^2 = 0.80$  and standard error of the estimate = 0.49. The traditional equations of Lohman and Slaughter showed poor performance in estimating body fat in children and adolescents living with HIV. The prediction models using anthropometry provided reliable estimates and can be used by clinicians and healthcare professionals to monitor total body and trunk fat in children and adolescents living with HIV.

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## Introduction

Children and adolescents living with HIV undergoing highly active antiretroviral therapy (HAART) often exhibit changes in body fat such as lipoatrophy (loss), lipohypertrophy (central accumulation), or a combination of both.<sup>1</sup> These changes are associated with metabolic abnormalities such as

mitochondrial toxicity, dyslipidemia, and insulin resistance, which can increase the risk of cardiovascular and cerebrovascular diseases.<sup>2</sup> Moreover, changes in body fat can affect body image perception, cause poor adherence to HAART, and compromise quality of life.<sup>3</sup>

The prevalence of lipodystrophy ranges from 26% to 55% among children and adolescents living with HIV.<sup>4-6</sup> This variability can be attributed to the subjectivity of visual inspection

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– mainly used for diagnosis – and to differences in time of exposure and in type of HAART. Objective methods have been used for measuring body fat.<sup>7,8</sup> Air-displacement plethysmography is a precise densitometric method for evaluating body fat, while dual energy X-ray absorptiometry (DXA) is an imaging-based alternative technique. DXA is a safe and accurate method,<sup>9</sup> especially when a more comprehensive compartmental analysis of body composition is required. However, both methods are expensive and require sophisticated infrastructure and human resources, thus rendering the application of these assessments difficult under conditions of limited resources.

Anthropometry is a noninvasive, low-cost and easy-to-use method that could be applied as an alternative to estimate body fat. Skinfold thickness studies have been performed to estimate body fat in the general population because of the increase in obesity.<sup>10</sup> However, it is unknown whether the commonly used equations of Lohman<sup>11</sup> and Slaughter<sup>12</sup> are valid for children and adolescents living with HIV. Studies have used these equations indiscriminately to predict body fat<sup>13</sup> or skinfold to evaluate thickness of subcutaneous body fat.<sup>14,15</sup> However, the predictive value of anthropometric measurements to estimate body fat using specific equations requires further investigation. The aim of this study was to assess the validity of traditional anthropometric equations and to develop predictive equations of total body fat and trunk fat for children and adolescents living with HIV based on anthropometric measurements.

## Methods

### Study design and patient population

This was a cross-validation study completed in 2010 in Florianópolis, capital of the State of Santa Catarina, southern Brazil. The city has the third highest human development index (0.847) in Brazil (average of 0.727). The GINI coefficient, a measure of inequality of income distribution, is 0.566 in Florianópolis, while this index ranges from 0.284 to 0.808 in Brazil.<sup>16</sup>

The target population were children and adolescents living with HIV acquired by mother-to-child transmission who were followed up at a referral hospital for the treatment of pediatric HIV infection. Patients were selected based on a screening performed in 2008 and participation in a previous study.<sup>17</sup> The criteria for inclusion were mother-to-child transmission of HIV reported in the medical records, age 7–17 years, availability of clinical and laboratory records, receiving care at this hospital, absence of concomitant diseases, and no use of diuretic agents that could alter body composition.<sup>18</sup>

### Dual-energy X-ray absorptiometry (DXA)

Total, segmental and percentage of body fat were evaluated by DXA using the Hologic Discovery WI Fan-Bean<sup>®</sup> system (Bedford, MA, USA). X-ray attenuation was computed using pediatric software (version 14.4:5). This method has been used for body composition analysis because it provides reproducible and accurate measurements of body fat.<sup>9</sup> In addition,

the technique is safe and emits radiation of 4.2–5.2  $\mu$ Sv, equivalent to the radiation received on a sunny day.<sup>9</sup> The equipment was calibrated daily as described by the manufacturer. Phantoms were used for calibration, guaranteeing internal quality control of the equipment. The coefficient of variation of the equipment during the study was 1% for bone mineral density evaluation as reported elsewhere.<sup>18</sup> For the assessment, the participants wore appropriate clothing without metal and were barefoot. The measurements were standardized and performed by two radiology technicians. Whole-body composition assessment by DXA was completed within approximately 10 min. The body fat percentage was obtained and age-, sex- and ethnicity-specific z-scores were calculated based on LMS values.<sup>19</sup>

### Anthropometry

All anthropometric measurements were performed according to the Anthropometric Standardization Reference Manual.<sup>20</sup> Height was measured with a Tonelli<sup>®</sup> stadiometer (120A; Criciúma, Brazil) to the nearest 1 mm, and body weight was measured with a Tanita<sup>®</sup> digital scale (BF683W, Arlington Heights, IL, USA) to the nearest 0.1 kg. The body mass index (BMI) was calculated based on height and weight.<sup>21</sup> Arm and waist circumference was measured with a non-elastic anthropometric tape to the nearest 0.1 cm.<sup>20</sup> Triceps, subscapular, abdominal, and calf skinfolds were measured with a Cescor<sup>®</sup> caliper to the nearest 0.1 mm.<sup>20</sup> The four skinfolds were used to calculate the trunk-limb ratio and sum of skinfolds ( $\sum$ 4 skinfolds). Body weight and height were measured in duplicate, while circumferences and skinfold thickness were obtained in triplicate. The means of the anthropometric variables were used for subsequent analysis.

All anthropometric measurements were taken individually in a private room. The examiners were previously trained and calibrated. Technical errors of measurement were established with 16 age- and sex-matched healthy peers. These errors were 0.19 cm and 0.51 kg for height and body weight, respectively, 0.22 and 0.52 cm for arm and waist circumference, respectively, and 0.41, 0.27, 0.44, and 0.50 mm for triceps, subscapular, abdominal and calf skinfolds, respectively. The intra-class correlation coefficients for the anthropometric measures ranged from 0.76 to 1.0. All anthropometric measures were adequate according to the International Society for the Advancement of Kinanthropometry.

The equations of Lohman and Slaughter were used to predict body fat for the cross-validation analysis. The equation of Lohman was developed to estimate body fat in children aged 6–17 years<sup>11</sup> and the equation of Slaughter for children aged 8–18 years.<sup>12</sup> Table 1 shows the two equations adjusted for sex, race and maturity.

### Demographic and clinical data

Age, sex, and skin color of the HIV-infected children and adolescents, as well as the socioeconomic and education level of the legal representative/parents, were collected using a questionnaire applied by interview. Immunological data and clinical symptoms, duration and type of HAART, HIV RNA viral load, and CD4<sup>+</sup> T lymphocyte count were obtained from the

**Table 1 – Traditional equations to estimate body fat in children and adolescents.**

Reference	Year	Sex	Predictive equation's
Lohman et al. <sup>12</sup>	1989	Boys/Girls (all ages)	%BF = 1.35 (TR + SE) – 0.012 (TR + SE) <sup>2</sup> – I <sup>a</sup>
Slaughter et al. <sup>13</sup>	1988	Boys (all ages)	%BF = 1.21 (TR + SE) – 0.008 (TR + SE) <sup>2</sup> + I <sup>b</sup>
Slaughter et al. <sup>13</sup>	1988	Girls (all ages)	%BF = 1.33 (TR + SE) – 0.013 (TR + SE) <sup>2</sup> – 2.5

<sup>a</sup> I, Intercept based on sex, age and ethnicity proposed by Lohman.<sup>12</sup>  
<sup>b</sup> I, Intercept substitutions based on maturation and ethnicity for boys proposed by Slaughter et al.<sup>13</sup> Prediction error for these equations ranged from 3.6 to 3.9% of body fat (BF).

medical records. Viral load was measured by branched-DNA assays and CD4<sup>+</sup> T lymphocyte count by flow cytometry. The progression of HIV infection was classified as asymptomatic or mild symptoms and moderate or severe symptoms.<sup>22,23</sup> Maturity was evaluated by self-assessment of secondary sex characteristics according to Tanner<sup>24</sup> after the participants were instructed by a researcher of the same sex about each stage.

### Statistical analysis

Skewness and kurtosis were analyzed using graphs and the Shapiro–Wilk test. The median and interquartile range were used to describe the distribution of the participants according to sex. The independent Student t-test or Mann–Whitney–U test were used to compare continuous variables between sexes. Correlations were calculated to identify predictors of total body fat, trunk fat, and body fat percentage using Pearson's linear correlation coefficient and Spearman's rank correlation for asymmetric variables. Linearity was analyzed graphically. Predictive variables at  $p < 0.05$  were selected for multiple linear regression analysis. Modeling was performed using a backward selection procedure and variables exhibiting low statistical significance  $p \geq 0.05$  were removed in decreasing order until the final model was obtained to predict total body and trunk fat. The models were evaluated using the regression coefficients and maximum likelihood test. For modeling, we considered the usefulness of the anthropometric measurements within the clinical context and features of HIV.

The body fat values estimated with our models and with the Lohman and Slaughter equations were compared using paired Student t-test with body fat measured by DXA. Lin's concordance correlation coefficient was used to test the association between data. Our models were analyzed using residuals, standard error of the estimate (SEE), multicollinearity, tolerance, variance inflation factor, Akaike's information criterion, and Bayesian information criterion. The Breusch-Pagan/Cook-Weisberg test was used to evaluate the heteroskedasticity of residuals. The dispersion of residuals was verified by the Bland–Altman method. Finally, bootstrap validation using 5000 bootstrap samples was performed to examine the internal validity of the models developed. Statistical analysis was performed using the STATA<sup>®</sup> 11.0 (Stata Corporation, College Station, TX, USA) and GraphPad Prism<sup>®</sup> 5.0 (GraphPad Software, Inc., San Diego, CA, USA) software packages.

The hospital's Institutional Review Board approved the study protocol (Approval No. 77/2009). Participation in the

study was voluntary and all respondents/legal representatives signed an informed consent form prior to the study.

### Results

The sample consisted of 48 children and adolescents living with HIV. Most of the participants had white skin color (56.3%), were from families with a household income of up to two minimum wages (47.9%), and were in the first three stages of sexual maturity (66.6%). Regarding clinical condition, most participants were asymptomatic or had mild symptoms (52.1%), had moderate immunosuppression (58.3%), and received non-protease inhibitor HAART (58.3%). Most adolescents were eutrophic (87.5%), but girls exhibited greater skinfolds and body fat by DXA than boys (Table 2).

As can be seen in Table 3, subscapular skinfold, the sum of four skinfolds and abdominal skinfold were linearly correlated with total body fat. For trunk fat, subscapular skinfold showed a higher correlation than BMI and abdominal skinfold.

Table 4 shows the prediction models of total body fat and trunk fat. Model 1 explained 85% of total body fat measured by DXA based on subscapular skinfold (standardized beta coefficient [ $\beta_{\text{standardized}}$ ] = 0.38), sum of four skinfolds ( $\beta_{\text{standardized}}$  = 0.71), abdominal skinfold ( $\beta_{\text{standardized}}$  = -0.33), sex ( $\beta_{\text{standardized}}$  = -0.20), and height ( $\beta_{\text{standardized}}$  = 0.26). The SEE of this model was low (1.42 kg). Model 2 explained 80% of the variance in trunk fat, with an SEE of 0.49 kg, based on subscapular skinfold ( $\beta_{\text{standardized}}$  = 0.63), age ( $\beta_{\text{standardized}}$  = 0.31), and sex ( $\beta_{\text{standardized}}$  = -0.21).

There was no difference between the total body fat values measured by DXA and those estimated with Model 1 (Table 5). Similarly, no difference was observed between trunk fat values measured by DXA and those estimated with Model 2 ( $p > 0.05$ ). In addition, Lin's concordance correlation coefficients were of moderate to substantial magnitude (Model 1 = 0.93; Model 2 = 0.90). However, there was a significant difference between the body fat values predicted with the equations of Lohman and Slaughter and the DXA values.

Fig. 1 shows linearity of measured body fat and body fat predicted with our models. Bland–Altman analysis of residuals is shown in Fig. 2. A random distribution of residuals was only found for total body fat ( $\chi^2 = 1.93$  and  $p = 0.1649$ ), but not for trunk fat ( $\chi^2 = 15.51$  and  $p < 0.001$ ). The same was observed for the equations of Lohman and Slaughter. Internal validation using 5000 bootstrap samples produced a corrected  $R^2$  of 85% and 80% for Models 1 and 2, respectively.

**Table 2 – Characteristics of the 48 HIV-positive children and adolescents.**

Variables	Boys (n = 24)		Girls (n = 24)	
	Median	25th; 75th	Median	25th; 75th
Age (years)	13.22	11.09; 14.70	12.37	9.39; 14.99
Body weight (kg)	40.90	30.45; 46.90	38.35	30.45; 48.00
Height (cm)	150.15	138.60; 160.55	148.6	133.3; 153.25
BMI (kg m <sup>-2</sup> )	17.64	15.94; 18.83	17.98	16.48; 20.43
Arm circumference (cm)	21.05	18.62; 23.77	21.30	19.80; 25.23
Waist circumference (cm)	64.22	58.18; 68.43	62.43	57.75; 65.37
Subscapular skinfold (mm)	5.48 <sup>a</sup>	5.07; 6.28	7.22	6.20; 9.18
Tricipital skinfold (mm)	7.48 <sup>a</sup>	5.97; 8.83	10.48	8.80; 12.35
Abdominal skinfold (mm)	6.35 <sup>a</sup>	4.92; 9.20	11.37	8.67; 14.17
Calf skinfold (mm)	6.57 <sup>a</sup>	6.05; 8.20	9.43	7.40; 10.60
∑4 skinfolds	26.13 <sup>a</sup>	21.83; 31.80	40.50	33.20; 46.43
TLR of skinfolds	0.86	0.75; 0.96	0.91	0.81; 0.98
Total body fat (kg)	5.89 <sup>a</sup>	5.70; 8.98	9.76	6.95; 15.19
Total body fat (%)	17.1 <sup>a</sup>	13.00; 20.10	27.55	23.9; 33.15
Body fat percent (escore-z)	-1.50 <sup>a</sup>	-2.39; -0.46	-0.58	-1.31; 0.26
Trunk body fat (kg)	1.98 <sup>a</sup>	1.74; 3.40	3.60	2.65; 5.89
Viral load (log)	1.69	1.69; 2.67	1.69	1.69; 3.14
T CD4 <sup>+</sup> Lymphocyte (mm <sup>3</sup> )	731.50	528.5; 1134.5	787.00	547.5; 957.50
Time of HAART (years)	8.51	4.30; 11.19	9.22	6.80; 12.03
	<b>n (%)</b>		<b>n (%)</b>	
Skin color				
White	13 (54.16%)		14 (58.33%)	
Mulatto/Black	11 (45.83%)		10 (41.66%)	
Clinical symptoms				
Asymptomatic/Mild	11 (45.83%)		14 (58.33%)	
Moderate/Severe	13 (54.17%)		10 (41.67%)	
Immunosuppression				
Absence	6 (25.0%)		3 (12.50%)	
Moderate	13 (54.17%)		15 (62.50%)	
Severe	5 (20.83%)		6 (25.00%)	
Type of HAART				
With PI;	9 (37.50%)		11 (45.83%)	
Without PI	15 (62.50%)		13 (54.17%)	

Abb: BMI, body mass index; ∑4 Skinfolds, sum of four skinfolds (subscapular, abdominal, calf and tricipital); TLR, trunk limb ratio; BF, body fat; HIV, human immunodeficiency virus.

<sup>a</sup> p < 0.05, between sexes (independent Student's T test; Mann-Whitney rank test).

## Discussion

The main findings of this study were that subscapular skinfold, the sum of four skinfolds, abdominal skinfold, sex, and height explained 85% of total body fat. Moreover, subscapular skinfold, age, and sex explained 80% of trunk fat in children and adolescents living with HIV. Although correlated with DXA-measured body fat, the traditional equations of Lohman and Slaughter underestimated total body fat by 8%. These findings demonstrate that our models based on anthropometric measurements can be used by clinicians and healthcare professionals as an objective, noninvasive and inexpensive alternative to assess body fat in children and adolescents living with HIV.

Models 1 and 2 developed in the present study can be used to estimate total body fat and trunk fat, respectively, showing high predictive power and agreement with the DXA method. In addition, a low error of estimation was found. These models represent a practical tool for the assessment of body fat in

the clinical setting, although some variability in body fat may occur due to growth and sexual dimorphism, which interfere with the prediction and interpretation of the results.<sup>25,26</sup> However, it is important to include these variables in the equations since they are associated with lipodystrophy.<sup>1,14</sup>

Studies on HIV conducted in developed countries have frequently used DXA to analyze body fat patterns and the association with cardiometabolic diseases.<sup>8,27</sup> However, the high cost of the equipment and the need for adequate infrastructure and personnel restrict the use of this method for body fat assessment when resources are limited. The development of specific anthropometric equations for children and adolescents with HIV is important for monitoring body fat (Model 1) because of the changes that result from HAART and HIV infection itself.<sup>1</sup> Although no cut-off points that define abnormalities are available, it is evident that the children and adolescents evaluated in this study are suffering from a reduction in body fat since negative median z-scores were found, especially in boys (Table 2), indicating a lipodystrophy phenotype.

**Table 3 – Correlation between DXA body fat and anthropometric/clinical variables.**

Variables	Total BF (kg)	Trunk BF (kg)
	Pearson's correlation coefficient (r)	
Age (years)	0.50 <sup>a</sup>	0.55 <sup>a</sup>
Body weight (kg)	0.63 <sup>a</sup>	0.68 <sup>a</sup>
Height (cm)	0.44 <sup>a</sup>	0.49 <sup>a</sup>
BMI (kg m <sup>-2</sup> )	0.76 <sup>a</sup>	0.80 <sup>a</sup>
Arm circumference (cm)	0.78 <sup>a</sup>	0.70 <sup>a</sup>
Waist circumference (cm)	0.51 <sup>a</sup>	0.58 <sup>a</sup>
Subscapular skinfold (mm)	0.87 <sup>a</sup>	0.85 <sup>a</sup>
Tricipital skinfold (mm)	0.72 <sup>a</sup>	0.62 <sup>a</sup>
Abdominal skinfold (mm)	0.80 <sup>a</sup>	0.78 <sup>a</sup>
Calf skinfold (mm)	0.77 <sup>a</sup>	0.66 <sup>a</sup>
∑ 4 skinfolds (mm)	0.84 <sup>a</sup>	0.77 <sup>a</sup>
TLR of skinfolds	0.31 <sup>c</sup>	0.44 <sup>c</sup>
Viral load (log)	0.17	0.11
CD4 <sup>+</sup> Lymphocyte (cells mm <sup>-3</sup> )	-0.33 <sup>c</sup>	-0.28
Time of HAART (years)	0.20	0.27
Sex (male; female)	-0.50 <sup>b</sup>	-0.45 <sup>b</sup>
Skin color (white; mulatto/black)	-0.01	0.04
Clinical symptoms (asymptomatic/mild; moderate/severe)	-0.15	-0.15
Type of HAART (with PI; without PI)	-0.26	-0.23

Note: For categorical and non-parametric variables was used Spearman Rank Correlation.

Abbr: BF, body fat; BMI, body mass index; HAART, combination antiretroviral therapy; PI, protease inhibitors; HIV, human immunodeficiency virus.

<sup>a</sup>  $p < 0.001$ .

<sup>b</sup>  $p < 0.01$ .

<sup>c</sup>  $p < 0.05$ .

Lipohypertrophy consists of the accumulation of adipose tissue and normally involves the intra-abdominal (increased visceral adipose tissue), breast, anterior neck, and dorsocervical regions.<sup>1</sup> For this study, Model 2 was developed to assess fat in the trunk area – from the top of the iliac crest to the base of the skull – using subscapular skinfold which is highly correlated with DXA values (Table 2). This assessment is important since the accumulation of trunk fat is commonly associated with dyslipidemia, insulin resistance,<sup>2</sup> and high intima-media

carotid thickness<sup>17</sup> in children and adolescents living with HIV and can lead to poor adherence to and failure of treatment.

Previous studies have reported correlations between anthropometric equations and DXA in healthy children and adolescents.<sup>25,26,28,29</sup> Although DXA is a reproducible and accurate technique for the measurement of body fat, Silva et al.<sup>10</sup> alerted to the development of equations using a multi-compartment approach in pediatric studies because of individual variability in the composition of fat-free mass.

**Table 4 – Multiple regression models for the prediction of total body mass in children and adolescents living with HIV.**

	R <sup>2</sup> adjusted	SEE	RMSE	F	AIC* <sub>n</sub>	BIC <sup>†</sup>	T	VIF
<i>Dependent variable</i>								
Total body fat (kg)								
<i>Model 1<sup>a</sup></i>								
Y = -10.35622 + (subscapular skinfold * 0.6324226) + (∑ 4 skinfolds * 0.2356916) + (abdominal skinfold * -0.2812848) + (sex * -1.538853) + (height * 0.0664786)	0.85	1.43	1.539	50.79	172.092	-71.707	0.15	4.09
<i>Dependent variable</i>								
Trunk body fat (kg)								
<i>Model 2<sup>a</sup></i>								
Y = -3.000654 + (subscapular skinfold * 0.5448779) + (age * 0.2481382) + (sex * -0.9241555)	0.80	0.49	0.982	63.80	138.38	-68.889	0.20	1.45

Note: Skinfolds (mm); Age (years); Height (cm); Sex (0 = female, 1 = male).

Abbr: ∑ 4Skinfolds, sum of four skinfolds; SEE, standard error of the estimate; RMSE, root mean square error; AIC, Akaike's information criterion; BIC, Bayesian information criterion; T, tolerance; VIF, variance inflation factor; HIV, human immunodeficiency virus.

<sup>a</sup>  $p < 0.001$ .

**Table 5 – Comparison between body fat measured by DXA and estimated by equations.**

	Mean (SD)	Rho (p)	TE	AD
Total BF <sub>DXA</sub> (kg)	9.225 (3.972)			
Total BF <sub>model1</sub> (kg)	8.443 (3.698)	0.93 (<0.001)	0.200	0.166
Trunk BF <sub>DXA</sub> (kg)	3.410 (2.199)			
Trunk BF <sub>model 2</sub> (kg)	3.580 (1.983)	0.90 (<0.001)	0.161	0.170
Total BF <sub>DXA</sub> (%)	22.954 (8.545)			
Total BF <sub>Lohman</sub> (%)	14.511 (5.240) <sup>a</sup>	0.43 (<0.001)	1.420	-8.443
Total BF <sub>Slaughter</sub> (%)	14.526 (5.218) <sup>a</sup>	0.42 (<0.001)	1.182	-6.907

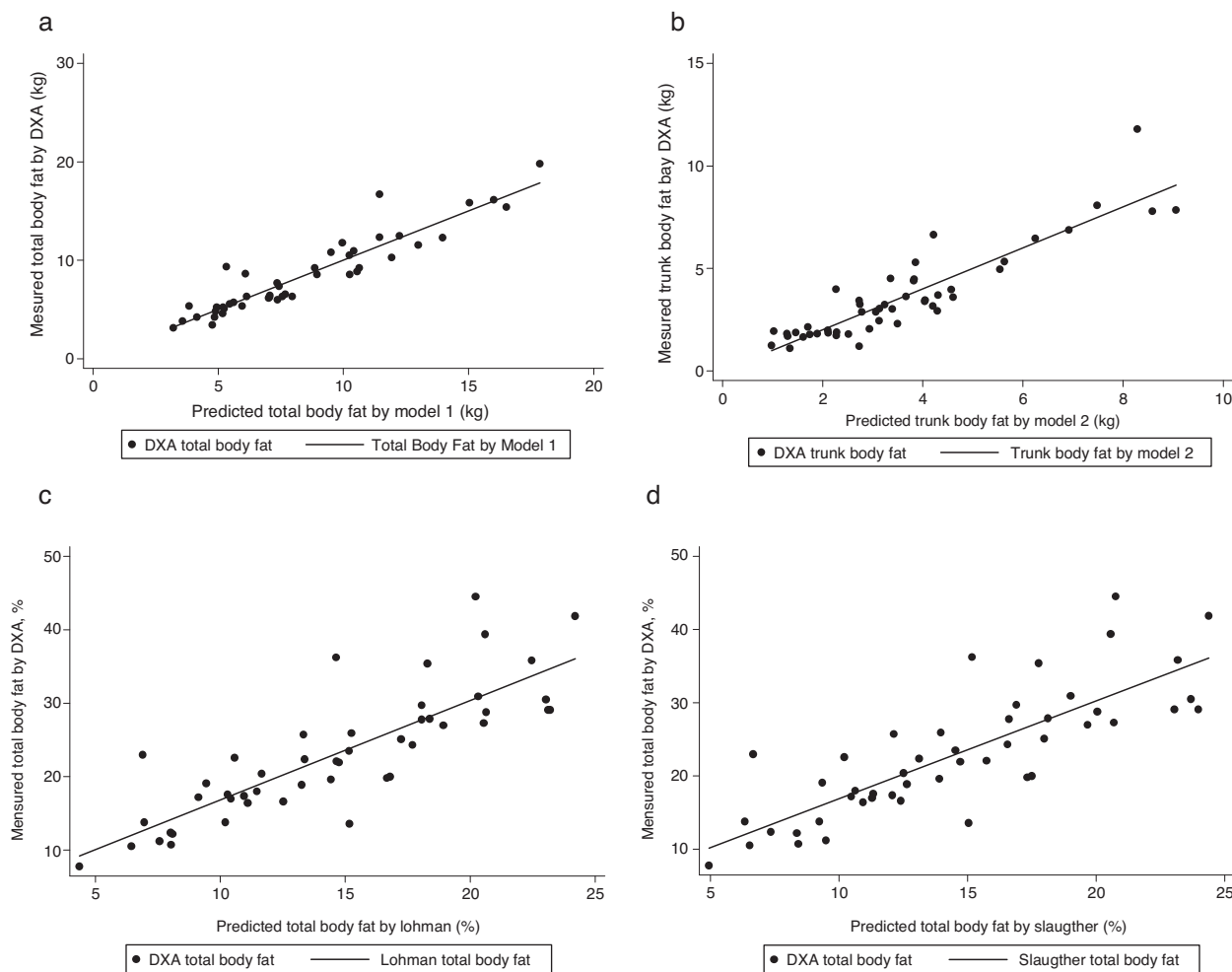
Abbr: Rho, Lin's concordance correlation coefficient; TE, total error; AD, average difference between measured and estimated values; BF, body fat; DXA, dual-energy X-ray absorptiometry; SD, standard deviation; p, p-value; HIV, human immunodeficiency virus.

Note: There was no difference between the mean values obtained by DXA and those estimated with the models (t-test < 0.0001).

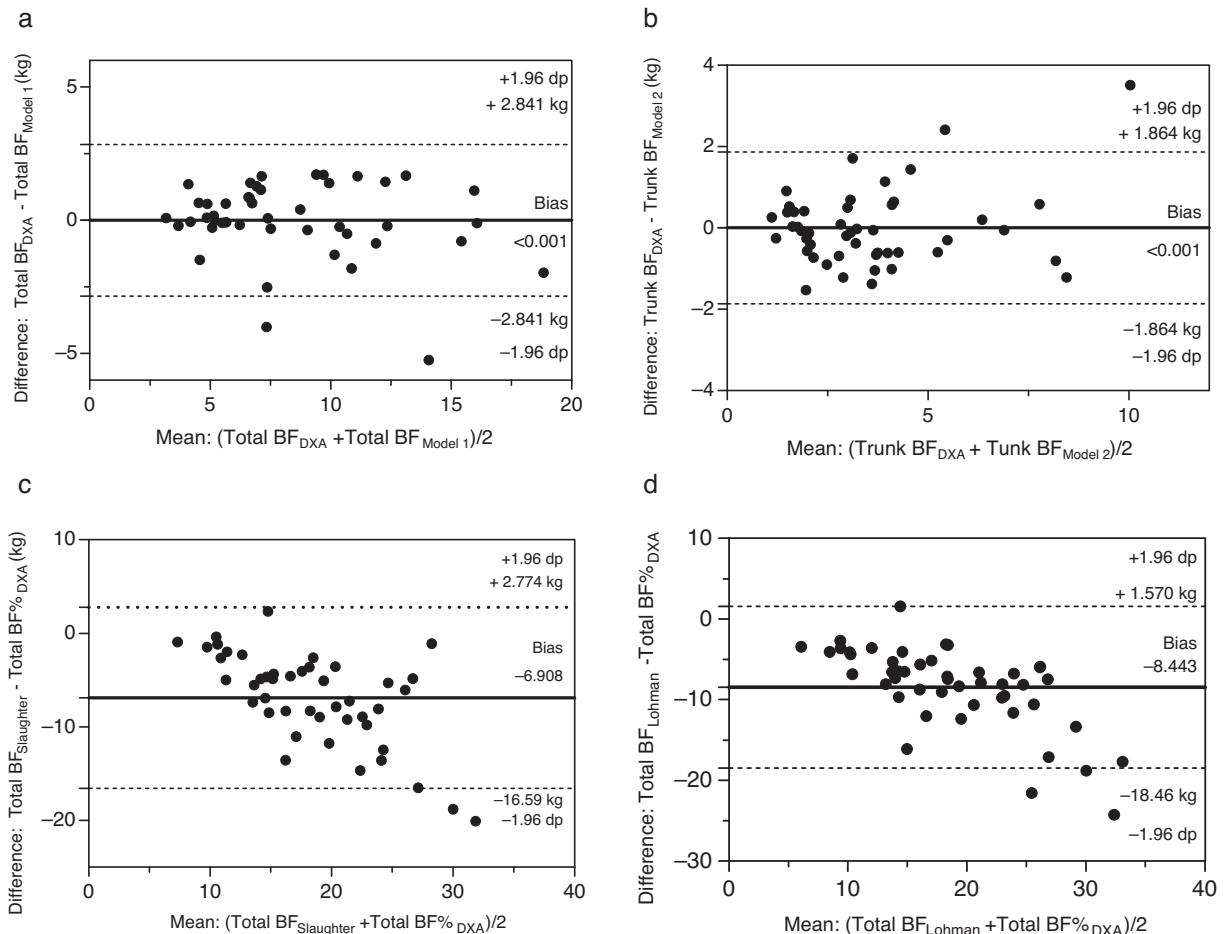
<sup>a</sup> Slaughter (t-test = 11.1350) and Lohman equation (t-test = -11.4505) are different from DXA values. SEE<sub>Lohman</sub> = 1.805% and SEE<sub>Slaughter</sub> = 1.283%.

Moreover, the validity of the response variable is determinant for the development of appropriate equations based on anthropometry.<sup>10</sup> Most validity studies of anthropometric equations in healthy children and adolescents have used DXA as the reference method.<sup>10</sup> DXA was also used as the reference method to assess body fat in this study. Advantages of

this method are its three-compartment approach, good precision, wide availability, and low radiation dose. However, DXA systems are not interchangeable and generalization is not possible, thus differences in developing predictive equations might be due to the use of different densitometers, softwares and/or scan modes.<sup>10</sup>



**Fig. 1 – Association between body fat measured by DXA (total [kg] and trunk [kg]) and predicted by the equations developed (Total BF<sub>model1</sub>[a], Trunk BF<sub>model 2</sub>[b] and Total BF<sub>Lohman</sub>[c] and Total BF<sub>Slaughter</sub>[d]) in children and adolescents living with HIV.**



**Fig. 2 – Analysis of residual scores of total body fat [BF] (a), trunk body fat (b) measured by DXA, prediction models and by Slaughter (c) and Lohman (d) equations in children and adolescents living with HIV.**

The equations of Lohman<sup>11</sup> and Slaughter<sup>12</sup> were not valid for estimating body fat in pediatric patients with HIV and their performance was lower than that of the equations developed in this study. These differences may be due to the reference methods used since the equations of Slaughter and Lohman were developed based on hydrostatic weighing, a densitometric method. However, in a study conducted on healthy Chinese children and adolescents with a similar age profile as the participants of the present study, the equation of Lohman was found to be a good predictor of body fat.<sup>28</sup> In contrast, Mast et al.<sup>30</sup> and Freedman et al.<sup>29</sup> reported the equations of Lohman and Slaughter, respectively, to overestimate body fat in healthy children and adolescents compared to DXA.

Since limitations of the Lohman and Slaughter equations were found for the healthy population, some disagreement is expected in HIV-infected individuals due to body fat abnormalities. Children and adolescents living with HIV infected by mother-to-child transmission exhibit a delay in sexual development and low height and weight for age<sup>31</sup> resulting from dysfunction of the hypothalamic-pituitary-adrenal axis.<sup>32</sup> Evidently, the variability in growth and development will significantly change the body composition expected for age and render the traditional body fat equations impractical in this population. Therefore, we suggest the use of Models

1 and 2 to assess total body fat and trunk fat, respectively. Usually the validation process uses 2/3 of the sample for developing the prediction equation and 1/3 for cross-validation of the model. This was not possible in our study because of the small size and we have therefore used a bootstrap procedure of 5000 simulations for internal validation.

Some limitations suggest caution in the interpretation of the data obtained with regression models, such as the fact that the sample was from only one Brazilian region and the size of the sample used as reference. The strengths of the present study include the high coefficients of determination of the models (80% and 85%) and the low SEE. Furthermore, the practicality of anthropometry to monitor total body and trunk fat in the clinical setting was considered in the development of the models. The models were developed for children and adolescents living with HIV using a heterogeneous sample in terms of protease inhibitor use, clinical and immunological symptoms, and viral load, which can represent many limited-resources scenarios.

## Conclusions

The models developed in this study for predicting total body and trunk fat in children and adolescents living with HIV

based on anthropometric and demographic variables showed a high predictive power and agreed with the DXA method as demonstrated by an SEE of virtually zero. The traditional equations of Lohman and Slaughter showed poor performance and are not indicated for body fat assessment in pediatric HIV infection. Our prediction models (1 and 2) can be useful to monitor body fat in patients living with HIV, especially under conditions of limited resources because anthropometry is a noninvasive, low-cost and easy-to-use method.

### Authors' contribution

Luiz R. A. de Lima conceived and designed the study, coordinated the data collection, interpreted the data, and wrote the manuscript. Priscila C. Martins, João A. C. de Castro and Carlos A. S. Alves Junior wrote the manuscript and analyzed and interpreted the data. Diego A. S. Silva and Edio L. Petroski interpreted the data and critically revised the study. All authors read and approved the final version of the manuscript.

### Conflicts of interest

The authors declare no conflicts of interest.

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