Original article

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

Luiz Rodrigo Augustemak de Lima*, Priscila Custódio Martins, Carlos Alencar Souza Alves Junior, João Antônio Chula de Castro, Diego Augusto Santos Silva, Edio Luiz Petroski

Universidade Federal de Santa Catarina, Centro de Desportos, Programa de Graduação em Educação Física, Florianópolis, SC, Brazil

ARTICLE INFO

Article history:
Received 11 December 2016
Accepted 3 March 2017
Available online 19 May 2017

Keywords:
Body fat
HIV
Skinfold thickness
Anthropometry
DXA

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, subcapular, 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.

© 2017 Sociedade Brasileira de Infectologia. Published by Elsevier Editora Ltda. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

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. 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. Moreover, changes in body fat can affect body image perception, cause poor adherence to HAART, and compromise quality of life.

The prevalence of lipodystrophy ranges from 26% to 55% among children and adolescents living with HIV. This variability can be attributed to the subjectivity of visual inspection...
– 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. 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, 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. However, it is unknown whether the commonly used equations of Lohman and Slaughter are valid for children and adolescents living with HIV. Studies have used these equations indiscriminately to predict body fat or skinfold to evaluate thickness of subcutaneous body fat. 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.

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. 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.

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

Total, segmental and percentage of body fat were evaluated by DXA using the Hologic Discovery WI Fan-Bean 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. In addition, the technique is safe and emits radiation of 4.2–5.2 μSv, equivalent to the radiation received on a sunny day. 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. 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.

**Anthropometry**

All anthropometric measurements were performed according to the Anthropometric Standardization Reference Manual. Height was measured with a Tonelli® stadiometer (120A; Criquiama, Brazil) to the nearest 1 mm, and body weight was measured with a Tanita® 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. Arm and waist circumference was measured with a non-elastic anthropometric tape to the nearest 0.1 cm. Triceps, subscapular, abdominal, and calf skinfolds were measured with a Cescorf® caliper to the nearest 0.1 mm. The four skinfolds were used to calculate the trunk-limb ratio and sum of skinfolds (Σ4 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 and the equation of Slaughter for children aged 8–18 years. 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+ T lymphocyte count were obtained from the
medical records. Viral load was measured by branched-DNA assays and CD4+ T lymphocyte count by flow cytometry. The progression of HIV infection was classified as asymptomatic or mild symptoms and moderate or severe symptoms. Maturity was evaluated by self-assessment of secondary sex characteristics according to Tanner 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–Wilks 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 > 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® 11.0 (Stata Corporation, College Station, TX, USA) and GraphPad Prism® 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 [βstandardized] = 0.38), sum of four skinfolds (βstandardized = 0.71), abdominal skinfold (βstandardized = –0.33), sex (βstandardized = –0.20), and height (βstandardized = 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 (βstandardized = 0.63), age (βstandardized = 0.31), and sex (βstandardized = –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.

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

| Reference                  | Year | Sex                  | Predictive equation’s |
|----------------------------|------|----------------------|-----------------------|
| Lohman et al.              | 1989 | Boys/Girls (all ages)| %BF = 1.35 (TR + SE) – 0.012 (TR + SE)² – I² |
| Slaughter et al.           | 1988 | Boys (all ages)      | %BF = 1.21 (TR + SE) – 0.008 (TR + SE)² + I² |
| Slaughter et al.           | 1988 | Girls (all ages)     | %BF = 1.33 (TR + SE) – 0.013 (TR + SE)² – 2.5 |

a 1, Intercept based on sex, age and ethnicity proposed by Lohman.
b 1, Intercept substitutions based on maturation and ethnicity for boys proposed by Slaughter et al. Prediction error for these equations ranged from 3.6 to 3.9% of body fat (BF).
Table 2 - Characteristics of the 48 HIV-positive children and adolescents.

| Variables | Boys (n = 24) | Girls (n = 24) |
|-----------|--------------|---------------|
| 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⁻²) | 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; 5.07; 6.28 | 7.22; 6.20; 9.18 |
| Tricipital skinfold (mm) | 7.48; 5.97; 8.83 | 10.48; 8.80; 12.35 |
| Abdominal skinfold (mm) | 6.35; 4.92; 9.20 | 11.37; 8.67; 14.17 |
| Calf skinfold (mm) | 6.57; 6.05; 8.20 | 9.43; 7.40; 10.60 |
| ∑4 skinfolds | 26.13; 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 (%) | 17.1; 13.00; 20.10 | 27.55; 23.9; 33.15 |
| Body fat percent (escore-2) | −1.50; −2.39; −0.46 | −0.58; −1.31; 0.26 |
| Trunk body fat (kg) | 1.98; 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⁺Lymphocyte (mm³) | 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 |

| Skin color | White | Mulatto/Black | n (%) |
|-----------|-------|---------------|-------|
|           | 13 (54.16%) | 11 (45.83%) | 14 (58.33%) |
| Clinical symptoms | Asymptomatic/Mild | Moderate/Severe | Immunosuppression |
|                | 11 (45.83%) | 13 (54.17%) | Absence |
|                | 6 (25.0%) | 13 (54.17%) | Moderate |
|                | 5 (20.83%) | 5 (20.83%) | Severe |
| Type of HAART | With PI | Without PI | n (%) |
|               | 9 (37.50%) | 15 (62.50%) | 11 (45.83%) |
|               | 9 (37.50%) | 15 (62.50%) | 13 (54.17%) |

Abbr: 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.

* * 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. However, it is important to include these variables in the equations since they are associated with lipodystrophy.

Studies on HIV conducted in developed countries have frequently used DXA to analyze body fat patterns and the association with cardiometabolic diseases. 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. 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>a</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>a</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.
Abbreviations: BF, body fat; BMI, body mass index; HAART, combination antiretroviral therapy; PI, protease inhibitors; HIV, human immunodeficiency virus.

Lipohypertrophy consists of the accumulation of adipose tissue and normally involves the intra-abdominal (increased visceral adipose tissue), breast, anterior neck, and dorsocervical regions. 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, and high intima-media carotid thickness 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. Although DXA is a reproducible and accurate technique for the measurement of body fat, Silva et al. 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.

| Dependent variable | R² adjusted | SEE | RMSE | F | AIC<sup>c</sup>n | BIC<sup>c</sup> | T | VIF |
|--------------------|-------------|-----|------|---|-----------------|----------------|---|-----|
| Total body fat (kg) |             |     |      |   |                 |                |   |     |
| Model 1<sup>a</sup> | 0.85 | 1.43 | 1.539 | 50.79 | 172.092 | −71.707 | 0.15 | 4.09 |
| Y = −10.35622 + (subscapular skinfold * 0.6324226) + (∑4 skinfolds * 0.2356916) + (abdominal skinfold * −0.2812848) + (sex * −1.538853) + (height * 0.0664786) |     |      |      |    |                |                |   |     |
| Dependent variable | Trunk body fat (kg) |     |      |   |                 |                |   |     |
| Model 2<sup>a</sup> | 0.80 | 0.49 | 0.982 | 63.80 | 138.38 | −68.889 | 0.20 | 1.45 |
| Y = −3.000654 + (subscapular skinfold * 0.5448779) + (age * 0.2481382) + (sex * −0.9241555) |     |      |      |    |                |                |   |     |

Note: Skinfolds (mm); Age (years); Height (cm); Sex (0 = female, 1 = male).
Abbreviations: 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.
Moreover, the validity of the response variable is determinant for the development of appropriate equations based on anthropometry. Most validity studies of anthropometric equations in healthy children and adolescents have used DXA as the reference method. 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.

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

|                      | Mean (SD)  | Rho (g) | 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%.

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.
The equations of Lohman\textsuperscript{11} and Slaughter\textsuperscript{12} 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.\cite{28} In contrast, Mast et al.\textsuperscript{29} and Freedman et al.\textsuperscript{29} 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\textsuperscript{31} resulting from dysfunction of the hypothalamic-pituitary-adrenal axis.\textsuperscript{32} 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.

Acknowledgments

The authors acknowledge the patients, investigators, Hospital Dia and Hospital Infantil Joana de Gusmão staff, especially Aroldo Prohmman de Carvalho. Also, we would like to thank Coordination of Improvement of Higher Education Personal (CAPES) for the awarded scholarships and Clínica Imagem for the assistance with DXA scans.

REFERENCES

1. Alves MD, Brites C, Sprinz E. HIV-associated lipodystrophy: a review from a Brazilian perspective. Ther Clin Risk Manag. 2014;10:559–66.
2. Fortuny F, Deya-Martinez A, Chiappini E, Galli L, de Martino M, Noguer-Julian A. Metabolic and renal adverse effects of antiretroviral therapy in HIV-infected children and adolescents. Pediatr Infect Dis J. 2015;34:S36–43.
3. Leite LHM, Papa A, Valentini RC. Body image dissatisfaction and adherence to antiretroviral therapy in people with HIV/AIDS. Rev Nutr. 2011;24:873–82.
4. European Paediatric Lipodystrophy Group. Antiretroviral therapy, fat redistribution and hyperlipidaemia in HIV-infected children in Europe. AIDS. 2004;18:1443–51.
5. Naufil A, Cortina-Borja M, Goethheuer T, Marcynska M, Viganò A, Thorne C. Body fat abnormality in HIV-infected children and adolescents living in Europe: prevalence and risk factors: fat abnormality in children. J Acquir Immune Defic Syndr. 2012;59:314.
6. Alam N, Cortina-Borja M, Goethheuer T, Marcynska M, Viganò A, Thorne C. Body fat abnormality in HIV-infected children and adolescents living in Europe: prevalence and risk factors. J Acquir Immune Defic Syndr. 2012;59:314–24.
7. Jacobson DL, Patel K, Siberry GK, et al. Body fat distribution in perinatally HIV-infected and HIV-exposed but uninfected children in the era of highly active antiretroviral therapy; outcomes from the Pediatric HIV/AIDS Cohort Study. Am J Clin Nutr. 2011;94:1485–95.
8. Arpadi SM, Bethel J, Horlick M, et al. Longitudinal changes in regional fat content in HIV-infected children and adolescents. AIDS. 2009;23:1501–9.
9. Helba M, Binkovitz LA. Pediatric body composition analysis with dual-energy X-ray absorptiometry. Pediatr Radiol. 2009;39:647–56.
10. Silva AM, Fields DA, Sardinha LB. A PRISMA-driven systematic review of predictive equations for assessing fat and fat-free mass in healthy children and adolescents using multicomponent molecular models as the reference method. J Obes. 2013:2013.
11. Lohman TG. Assessment of body composition in children. Pediatr Exerc Sci. 1989;1:19–30.
12. Slaughter MH, Lohman TG, Roisleau R, et al. Skinfold equations for estimation of body fatness in children and youth. Hum Biol. 1988;70:9–23.
13. Ramalho LC, Goncalves EM, de Carvalho WR, et al. Abnormalities in body composition and nutritional status in HIV-infected children and adolescents on antiretroviral therapy. Int J STD AIDS. 2011;22:453–6.
14. Jaquet D, Levine M, Ortega-Rodriguez E, et al. Clinical and metabolic presentation of the lipodystrophic syndrome in HIV-infected children. AIDS. 2000;14:2123–8.
15. Falchetti CZ, Patin RV, Gouvea AdF T.B., Szejnfeld VL, Succi RCDM, Oliveira FLC. Body composition and lipodystrophy in prepuberalt HIV-infected children. Braz J Infect Dis. 2013;17:01–7.
16. United Nations Development Programme. Institute for Applied Economic Research. João Pinheiro Foundation. Atlas of human development in Brazil, 2013. Available from: http://www.atlasbrasil.org.br/2013/pt/ [cited 11.09.14].
17. Giuliano ICB, de Freitas SF, de Souza M, Caramelli B. Subclinical atherosclerosis and cardiovascular risk factors in HIV-infected children: PERI study. Coron Artery Dis. 2008;19:167–72.
18. Lima LRA, Krug RR, Silva RC, et al. Prediction of areal bone mineral density and bone mineral content in children and adolescents living with HIV based on anthropometric variables. J Clin Densitom. 2016;19:457–64.
19. Kelly TL, Wilson KE, Heymsfield SB. Dual energy X-ray absorptiometry body composition reference values from NHANES. PLoS ONE. 2009;4:e7038.
20. Lohman TG, Roche AF, Martorell R. In: Abridged, editor. Anthropometric standardization reference manual. Champaign: Human Kinetics; 1991.
21. Onis M, Onyango AW, Borghi E, Siyam A,lishid C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. Bull World Health Organ. 2005;83:660–7.
22. Centers for Disease Control and Prevention. Revised Classification System for Human Immunodeficiency Virus Infection in Children Less Than 13 Years of Age. MMWR 43 (No. RR-12); 1994. p. 1–7.
23. Centers for Disease Control and Prevention. Revised Surveillance Case Definitions for HIV Infection Among Adults, Adolescents, and Children Aged <18 Months and for HIV Infection and AIDS Among Children Aged 18 Months to <13 Years — United States. MMWR 57 (No. RR-10); 2008. p 1–9.
24. Tanner JM. Growth at adolescence. 2nd ed. Oxford: Blackwell Scientific Publications; 1962.
25. Buonani C, Fernandez RA, Bueno DR, et al. Performance of different anthropometric equations that predict excess body fat in children and adolescents. Rev Nutr. 2011;24:41–50.
26. Flavel NA, Olds TS, Buckley JD, Haren MT, Petkov J. Anthropometric estimates of total and regional body fat in children aged 6–17 years. Acta Paediatr. 2012;101: 1253–9.
27. Aldrovandi GM, Lindsey JC, Jacobson DL, et al. Morphologic and metabolic abnormalities in vertically HIV-infected children and youth. AIDS. 2009;23:661–72.
28. Chan D, Li A, So H, Yin J, Nelson E. New skinfold-thickness equation for predicting percentage body fat in Chinese obese children. HK J Paediatr. 2009;14:96–102.
29. Freedman DS, Horlick M, Berenson GS. A comparison of the Slaughter skinfold-thickness equations and BMI in predicting body fatness and cardiovascular disease risk factor levels in children. Am J Clin Nutr. 2013;98:1417–24.
30. Mast M, Körtzinger I, König E, Müller M. Gender differences in fat mass of 5—year old children. Int J Obes. 1998;22:878-84.
31. de Martino M, Tovo PA, Galli L, et al. Puberty in perinatal HIV-1 infection: a multicentre longitudinal study of 212 children. AIDS. 2001;15:1527–34.
32. Laudat A, Blum L, Guechot J, et al. Changes in systemic gonadal and adrenal steroids in asymptomatic human immunodeficiency virus-infected men: relationship with the CD4 cell counts. Eur J Endocrinol. 1995;133:418–24.