ORIGINAL

VALIDATION OF EQUATIONS OF SKINFOLD THICKNESS FOR FAT MASS ESTIMATION IN HIV/AIDS SUBJECTS: A COMPARISON OF DUAL ENERGY X-RAY ABSORPTIOMETRY AND COMPUTED TOMOGRAPHY OF ABDOMEN

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Recebido: 24/11/2008
Re-submissão: 09/01/2009
Aceito: 28/01/2009

ABSTRACT

VALIDATION OF EQUATIONS OF SKINFOLD THICKNESS FOR FAT MASS ESTIMATION IN HIV/AIDS SUBJECTS: A COMPARISON OF DUAL ENERGY X-RAY ABSORPTIOMETRY AND COMPUTED TOMOGRAPHY OF ABDOMEN

The objective of the present study was to develope and to validate equations based on skinfold thickness for the estimation of percent body fat (%BF) in HIV/AIDS subjects using dual energy X-ray absorptiometry (DEXA) and computed tomography of abdomen (CTA) as the gold standards. The sample included 15 adult Brazilian HIV/AIDS subjects (10 men and 5 women). Mean age was 36.9 years (SD 8.2) and mean %BF by DEXA was 18.2 (SD 9.5). The estimation of %BF was done using linear regression models, and the independent variables were the sum of one to seven skinfold thickness. The skinfold thickness was compared with DEXA and CTA. The Durnin & Womersley equation was also tested. The best equation for males was [%BF = 3.385 + 0.279 * (axillary + subscapular); r2=0.83] and for females was [%BF = -24.323 + 0.736 * (suprailiac + abdominal + medial calf); r2=0.81]. The total error of the estimate of %BF in HIV/AIDS was <3.5%, the means were not different between males and females from the values measured by DEXA, and the estimated values were highly correlated with DEXA and CTA. The 95% limits of agreement between HIVE and DEXA by the Bland-Altman method were good. The Durnin & Womersley equation was also tested, and the values showed significant differences in the means (males) and the total error was >3.5% for males and females in the comparison with DEXA. The HIV/AIDS equation complied with all the validation criteria. We recommended this equation to be tested in larger samples for estimating %BF among HIV/AIDS subjects.

KEY-WORDS: body composition; HIV/AIDS; skinfold thickness; dual energy X-ray absorptiometry; computed tomography of abdomen.

INTRODUCTION

Changes in body composition such as accumulation of abdominal fat and metabolic abnormalities such as hyperlipidemia are factors present in the life of HIV/AIDS subjects who regularly use highly active antiretroviral therapy[1]. These changes obviously lead to increased risk for cardiovascular disease[2,3]. Imaging methods such as whole body dual energy X-ray absorptiometry (DEXA) and computed tomography of abdomen (CTA) are considered to be the gold standard for the measurement of body composition[4,5] and have been used in studies on HIV-infected subjects[1,6]. However, for developing countries such as Brazil, the cost of these exams is still very high, impairing and often preventing research on this area. An alternative for epidemiologic studies is to use more accessible methods anthropometrics as skinfold thickness (ST) in order to estimate the fat mass using equations. The search for an ideal equation for the estimate of body composition in the HIV/AIDS population has been the objective of some investigators[7]. Andrade et al (2002)[8] recently validated the Durnin & Womersley (1974) equation (DWE)[9] for the estimate of fat mass in American HIV/AIDS subjects, even though this equation has been extensively used for this specific population[6,7,10].

The objective of the present study was to develope and to validate equations for estimating fat mass in HIV/AIDS subjects (HIVE) living in a developing country.

METHODS

Subjects

The sample consisted of 15 HIV-infected adults, 10 men and 5 women. The study was conducted from October 2001 to February 2002. All subjects admitted to the study had been on highly active antiretroviral therapy including protease inhibitors and reverse transcriptase inhibitors for at least 3 months. Samples size was calculated based on the mean correlation coefficients obtained in previous studies carried out to validate the estimate of fat mass[5,11,12,13].

Data Collection

This was a validation study carried out in the AIDS Clinic, a health unit linked to the Department of Infectious Diseases of School of Medicine of São Paulo University. The unit is located in the central region of the São Paulo city and provides care for 4000 registered HIV/AIDS patients, being considered a reference center for multi-professional health care and for research on persons living with HIV/AIDS. The Research Ethics Committee of all institutions approved the study and all subjects gave written informed consent to participate.

Subjects were selected by consecutive sampling after a visit to the infectologist. Exclusion criteria were: presence of any active acute opportunistic infection that might influence the results of analysis of body composition at the time of evaluation, having been submitted to a surgical intervention such as liposculpture or liposuction up to three months before the study, presence of any disabling disease that would prevent measurements and examinations, being pregnant, and using corticosteroids, anabolic steroids and hormonal contraceptives because of the possible influence of these medications on body fat. DEXA and CTA were performed at the Radiology Institute of the University Hospital, São Paulo University, by technicians specifically trained.

Dual Energy X-ray Absorptiometry

DEXA used as the gold standard for the determination of fat mass. The exam was carried out using a model QDR 4500 Hologic apparatus (Hologic Inc., Waltham, MA, USA). Standard procedures were adopted to position the subjects during the acquisition phase of the exam. Patients were first instructed to remove any metal objects and their shoes and to lie in dorsal decubitus in the apparatus. Crosswise scans were then obtained from the head to the feet and the images were later analyzed with specific Hologic software. The fat mass was determined in percentual (%BF) and kilograms (kg).

Computed Tomography of Abdomen

CTA was used as the gold standard for the assessment of total abdominal fat on the L4-L5 plane. The procedure was carried out using a CT PACE apparatus (General Electric, Milwaukee, WI, USA). A digital image of the lumbar region was first obtained for the determination of the L4-L5 disc plane. The field of view was supposed to permit the visualization of the entire abdominal wall. The areas of visceral fat and subcutaneous fat as well as their sum were then measured on this image to determine total abdominal fat. For the determination of visceral fat area, a line was first traced with the electronic cursor along the fascia transversalis anterior and along the fascia of the square lumbar musculature posterior, excluding the vertebral body. After this region was delimited, the computer of the tomograph was programmed to calculate only the fat present in this region and the minimum and maximum coefficients of attenuation corresponding to fat were determined. Coefficients of –250 to –50 Hounsfield units were adopted in the present study. Thus, the equipment excluded from the calculation structures not consisting of fat. The area of subcutaneous fat was then calculated by tracing a line immediately external to the skin contouring the entire abdominal circumference. At the point where this line met the initial point of the tracing, the line was made to pass anteriorly to the muscular plane and internally to the skin plane along the entire abdominal circumference. The same procedure of non-fat structure exclusion was then repeated by adopting the same limit values of the coefficients of attenuation. The areas of visceral fat, subcutaneous fat and total abdominal fat were determined in squared centimeters (cm^2).

Anthropometrics Measures

The biceps, triceps, subscapular, axillary, suprailiac, abdominal, and medial calf ST were measured by the method of Norton et al (1996)[14]. Each ST was measured three times and the mean value of the three measurements was calculated. The ST was measured with a Lange caliper with 1.0 millimeters precision.

Height was measured three times and the mean value was calculated, and body weight was measured only once. The precision of the height measurement was 0.1 centimeters and the value was obtained using a Sanny anthropometric tape fixed to the wall of the measuring room. The precision of the weight measurement was 0.1 kilograms and the value was obtained with a Filizola digital scale. A specifically trained professional made all measurements with extensive experience in the area of measurement and evaluation.

Body Composition Equations

The DWE used at estimated body density was:

Women: Db(g/cc)=1.1567 -0.0717 * log∑ (biceps + triceps + subscapular + suprailiac)

Men: Db(g/cc)= 1.1765 -0.0744 * log∑ (biceps + triceps + subscapular + suprailiac)

At the estimated for %BF was used the formulas the Siri (1961)[15]:

$$\%BF = \left(\frac{4.95}{D_b} - 4.50 \right) * 100.$$

To create HIVE we used the ST variables. The DEXA and CTA were used as the gold standard for comparison with HIVE and DWE.

Statistical Analysis

For the elaboration of specific HIVE, we calculated the Pearson correlation coefficient between fat mass of DEXA and each ST. after this simple linear regression models were estimated simple linear regression models using one to seven ST as independent variable, which had the higher correlation was choose the begin procedure.

The Kolmogorov-Smirnov test showed that all variables had goodness-of-fitness for normal distribution and the intraclass correlation coefficient was used to estimate the relation between fat mass values obtained by DEXA and DWE and HIVE values. The Student t-test was used to compare the mean values obtained DEXA to those estimated by the DWE and HIVE equations. Total error of the equations was calculated according to Lohman (1992)[16]. The Bland & Altman method was used to analyze agreement between the DWE and HIVE in the comparison with DEXA. The Pearson correlation coefficient was used to estimate relation between total fat abdominal obtained by CTA and total fat mass obtained by HIVE.

The research was approved by the Research Ethics

Committee of the School of Public Health, University of São Paulo, and by the Research Projects Analysis Committee of the Hospital das Clinicas, School of Medicine, University of São Paulo.

RESULTS

Table 1 shows the clinical and anthropometric characteristics of the study population. Most of the population (60%) was within the age range up to 35 years. Mean time of use of highly active antiretroviral therapy was 37.6 ± 16.8 months for men and 40 ± 14.3 months for women. Only one man and one woman had CD4+ counts below 200 cells per cubic milimiter; however, since no problem was observed that might influence body composition at the time of collection, it was decided to keep them in the analysis. With respect to anthropometric data, mean fat mass varied significantly in both sexes.

When ST variables was correlated with %BF (data not shown), the magnitude of the correlations in increasing order was axillary, subscapular, abdominal, suprailiac, biceps, triceps and medial calf in men, suprailiac, abdominal, medial calf, axillary, biceps, triceps and subscapular in women. The equations for fat mass estimates are shown in **Table 2**. The best models were found to be 2 ST for men and 3 ST for women.

Comparison of the mean and correlation between the values measured by DEXA and those estimated by the equations showed that mean DWE values were significantly different in men in comparison with the DEXA (**Table 3**). For women, no variable variable was highly correlated, but no significant differences were observed between means the DWE in comparison with the DEXA. The total error of the DWE was high in both sexes. With respect to the HIVE equations (**Table 4**), the values were found to be highly correlated with DEXA and no significant differences were observed between means The HIVE in comparison with DEXA either in men or in women. The total error of the HIVE was low in both sexes.

The body fat in kg obtained for HIVE was correlated with total fat abdominal obtained by CTA (**Figure 1**). The %BF estimated for the HIVE had high agreement with the %BF measured for the DEXA (**Figure 2**).

Table 1
Subject characteristics

	Male (N=10)	Female (N=5)	Combined (N=15)
Age (years)	37.5 ± 9.9	35.8 ± 3.7	36.9 ± 8.2
Antiretroviral therapy (months)	37.6 ± 16.8	40.0 ± 14.3	38.8 ± 15.5
CD4 count (cells/mm^3)	437.7 ± 226.3	443.0 ± 211.8	439.5 ± 213.9
Height (cm)	172.1 ± 7.0	156.5 ± 2.0	166.9 ± 9.5
Weight (kg)	72.1 ± 16.7	59.3 ± 3.9	67.8 ± 14.9
BMI (kg/m^2)	24.2 ± 4.9	24.2 ± 2.0	24.2 ± 4.1
Percent of fat (DEXA)	14.1 ± 5.9	26.4 ± 10.5	18.2 ± 9.5
Computed Tomography (cm^2)	259.0 ± 142.2	213.8 ± 38.7	243.9 ± 117.4

Values are means ± s.d.

Table 2
Regression equations for the estimate of percentage of fat

Regression equations	r	r^2	s.e.e. (%)
Men			
%BF=5.062+0.496 * (AM)	0.91	0.81	2.56
%BF=3.385+0.279 * (AM+SB)1	**0.92**	**0.83**	**2.42**
%BF=3.970+0.168 * (AM+SB+AB)	0.91	0.81	2.55
%BF=4.185+0.126 * (AM+SB+AB+SI)	0.91	0.80	2.61
%BF=3.873+0.121 * (AM+SB+AB+SI+BI)	0.91	0.81	2.58
%BF=3.351+0.118 * (AM+SB+AB+SI+BI+TR)	0.92	0.82	2.46
%BF=3.023+0.112 * (AM+SB+AB+SI+BI+TR+MC)	0.92	0.82	2.46
Women			
%BF=-31.116+2.228 * (SI)	0.84	0.61	6.62
%BF=-26.047+0.843 * (SI+AB)	0.78	0.49	7.54
%BF=-24.323+0.736 * (SI+AB+MC)1	**0.92**	**0.81**	**4.62**
%BF=-28.112+0.623 * (SI+AB+MC+AM)	0.90	0.74	5.34
%BF=-28.311+0.557 * (SI+AB+MC+AM+BI)	0.88	0.71	5.72
%BF=-28.800+0.501 * (SI+AB+MC+AM+BI+TR)	0.89	0.73	5.44
%BF=-53.734+0.582 * (SI+AB+MC+AM+BI+TR+SB)	0.94	0.83	4.28

(BI), biceps; (TR), triceps; (SB), subscapular; (AM), axillary; (SI), suprailiac; (AB), abdominal; (MC), medial calf; (WC); 1. used equations

Table 3
Comparison of percentage of fat measured by DEXA and estimated by EHIV and DWE

	mean (s.d.)	T test (p)	ICC (r)	TE (%)
Males				
$\%BF_{DEXA}$	14.1 ± 5.9			
$\%BF_{HIVE}$	14.1 ± 5.4	0.986*	0.92**	2.0
$\%BF_{DWE}$	20.5 ± 6.8	<0.001*	0.71**	6.7
Females				
$\%BF_{DEXA}$	26.4 ± 10.5			
$\%BF_{HIVE}$	26.4 ± 9.8	0.999*	0.86**	2.4
$\%BF_{DWE}$	34.0 ± 1.4	0.145*	0.03**	4.0
Combined				
$\%BF_{DEXA}$	18.2 ± 9.5			
$\%BF_{HIVE}$	18.2 ± 2.3	0.993	0.96	2.2
$\%BF_{DWE}$	25.0 ± 2.2	<0.001	0.65	5.3

*(ICC) Intraclass correlation coefficient; *in comparison with $\%BF_{DEXA}$*
(TE) Total error $= \sqrt{\sum (y-y')^2 / N}$
$**p<0.05$

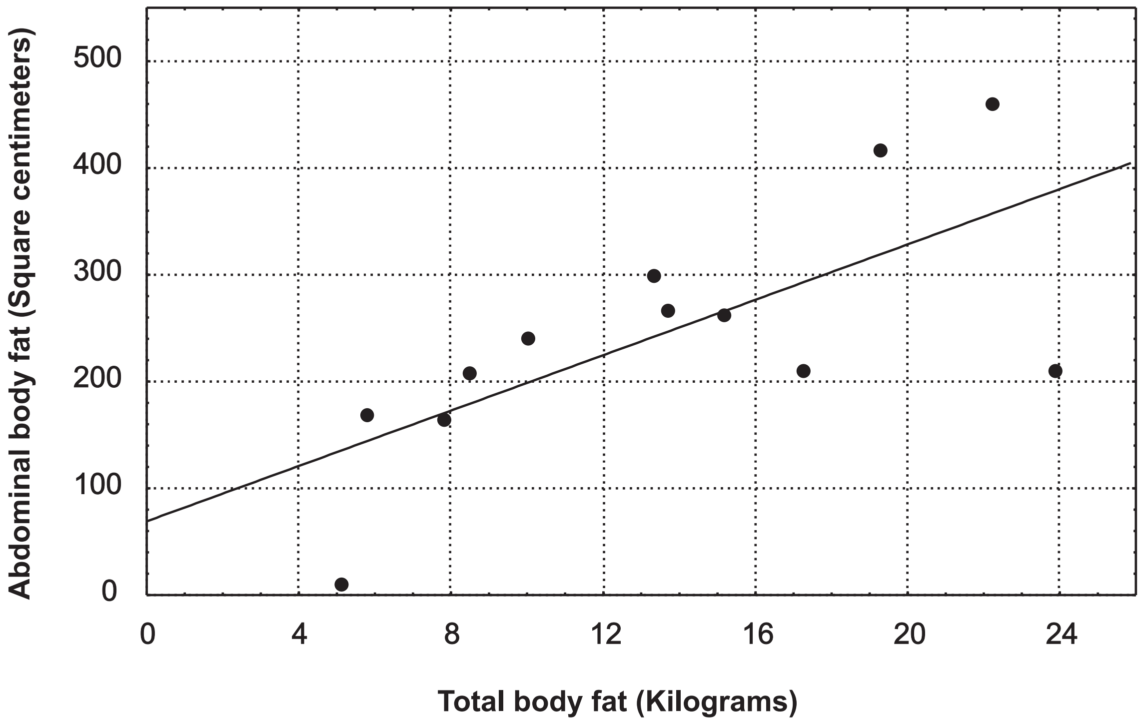

Figure 1
Relationship between abdominal body fat by CTA with total body fat by HIVE (r=0.69; p=0.012) (combined male and female).

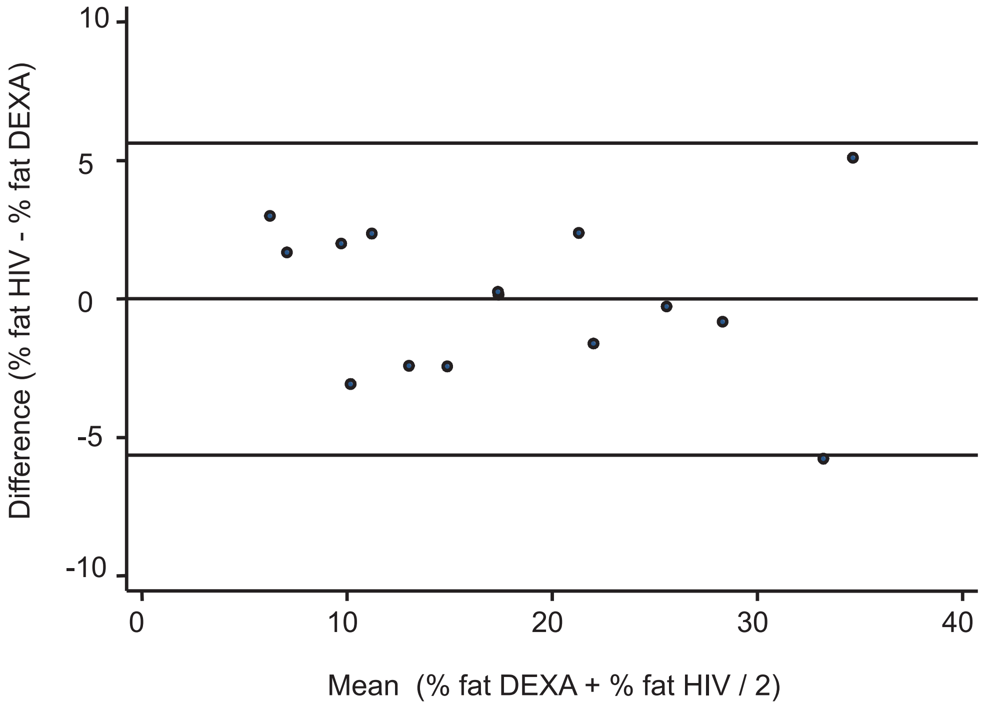

Figure 2
Comparison of the %BF HIVE equation with %BF DEXA through the Bland-Altman method (combined male and female).

DISCUSSION

Studies conducted in developed countries have attempted to determine the correlation between fat mass estimated by ST equations and the values measured by DEXA[5,11-13]. Other studies on HIV/AIDS subjects have also detected significant correlations between fat mass values obtained by ST equations and the values obtained by DEXA[6,10]. More recently, two other studies used DEXA and magnetic resonance to validate anthropometric equations for fat mass estimates in HIV/AIDS patients[7,8].

With respect to the elaboration of specific equations for fat mass estimate, in women the suprailiac, abdominal and medial calf ST may reflect a distribution of the gynoid type[16] mainly represented by the suprailiac ST, although with a tendency to accumulation in the abdominal region due to the phenomenon of fat redistribution represented by the abdominal ST. In addition, the medial calf ST may represent a loss of fat in the limbs. The axillary and subscapular ST represented well the distribution of fat observed in men in the present study, which may aggravate the already characteristic android effect commonly observed in males, consisting of a great accumulation of fat in the central region[16]. Bell et al (1995)[17] showed that the suprailiac ST was important for women and the subscapular ST was important for men at %BF estimate in an English population with growth hormone deficiency.

According to Lohman (1992)[16], correlation coefficients of 0.80 or higher are ideal for the validation equations when compared with standard measurements. In the present study we observed that DWE was well correlated with standard values in men, whereas low correlation coefficients were obtained for women. The studies using this DWE equation are controversial. Recently, Andrade et al. (2002)[8] showed that this equation was highly correlated with total fat measured by magnetic resonance in North American adult HIV/AIDS patients. Positive results were obtained for other populations, with correlations of more than 0.80 in adult Englishmen[11,17], in English female and male renal transplant recipients[12], in adult Australian men[5], and in adult Spanish men[18]. Other studies, however, have found correlations of less than 0.80 in the validation of this equation compared to standard values for English women[11] and for North American HIV/AIDS men[10].

With respect to the quality of the equations, although the methods may be well correlated there may be problems in agreement, especially concerning the estimate of fat mass[12]. DWE was found to overestimate both fat mass in men, with significant differences in mean values compared to standard values, whereas no such differences were observed for women. Other studies reported no significant differences in adult English women and men with growth hormone deficiency[17] or in adult and elderly Australian men[5]. However, studies on English recipients of kidney transplants[12] and on adult Spanish men[18] showed significant differences between the mean values predicted by this equation and the standard measured values. The mean values estimated by HIVE did not differ significantly from measured values.

The main problem of HIV/AIDS subjects is the accumulation of abdominal fat[1,3]. The HIVE was representative of this fat type, presenting relationship with the CTA.

Lohman (1992)[16] argued that it the total error for the estimate of %BF should not exceed 3.5%. DWE overestimated fat mass both in women and in men, whereas HIVE yielded errors within acceptable limits for both sexes. Other studies have shown that errors within acceptable limits were obtained with DWE when compared to gold standards in adult Spanish men[18], although the errors exceeded these limits in North American women[19].

One limitation of this study is that the cross-validation of the equation was not tested in a larger sample of HIV/aids subjects, which would be important to confirm the validity of the equations.

In view of the present results, we believe that the specific equations created for HIV/AIDS subjects in this study are highly suitable for the estimate of fat mass in this population, in addition to being better than the DWE.

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AGRADECIMENTOS:

Agradecemos à Fundação de Amparo a Pesquisa do Estado de São Paulo (FAPESP) pela bolsa de doutorado concedida a Alex Antonio Florindo (Processo 00/09482-8). Este estudo foi conduzido na clínica da AIDS, uma unidade de saúde vinculada ao Departamento de Moléstias Infecciosas e Parasitárias da Faculdade de Medicina da USP.

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