Development of an equation for measurement of bodyfat mass of elderly women with osteoporosis or osteopenia through skin fold thickness using dual energy X-ray absorptiometry as a reference

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ABSTRACT

Introduction and objective: The body composition has been intensively investigated as a determinant of bone mineral density. The present study was developed in order to propose a predictive equation to calculate body fat percentage by means of skin folds thickness using bone densitometry (DXA) as a reference in a group of elderly women with osteoporosis and osteopenia. **Methodology:** Twenty-nine women, mean age 67 to 84 years old, in attendance at the Osteoporosis Clinic at Rheumatology Division, School of Medicine, University of Sao Paulo, were evaluated. Four skin folds thickness were measured (biceps, triceps, subscapular and suprailiac) and body composition by DXA was evaluated. The statistical analysis consisted of Kolmogorov-Smirnov test, Pearson's coefficient correlation, simple linear regression analysis, intra-class correlation coefficient, *t* Student test, Bland-Altman test and calculus of equation total error according to Lohman (1992). **Results:** The best skinfold model that explained the percentage of body fat mass included the suprailiac, bicipital and tricipital values, determining up to 72% of body fat mass. The fat mass average values in kilograms estimated by the skin folds and measured by DXA were not statistically different and had been highly correlated ($r = 0.82$; $p < 0.001$). Comparing the fat mass percentage evaluated by the proposed equation and the percentage measured by DXA, the total error was of 0.7% and 0.4 kg. **Conclusion:** In view of the presented results, the resultant equation of the regression model is adequate for elderly women with osteoporosis and osteopenia, and may be an alternative for the body fat mass estimate in this population.

Keywords: Body composition. Bone mineral density. Elderly.

INTRODUCTION

Osteoporosis is a bone metabolism disorder which occurs in approximately 10 million of Brazilians as well as being an extensive public health problem[1]. Besides bone mass loss, peri and postmenopausal women present variations in their body composition and fat distribution. It has been observed weight increase; muscular mass loss and increase of body fat (BF); despite the activity of these alterations in the bone mass being controversial yet[2]. Body weight is well-accepted as an important determinant of the Bone Mineral Density (BMD) – weight increase leads to an increase of the bone mechanical strength and consequent decrease of the bone resorption. The divergences in this aspect involve the relation of weight components (adipose tissue and lean mass) with the BMD[2-3].

It is attributed to the adipose tissue the role of helper in the bone loss inhibition, where hormonal factors such as seric estrogen and leptin indices are combined, in order to induce the osteoblasts differentiation in the bone marrow, facilitating hence the bone formation and the mechanical action played by the body fat in the bone tissue. The lean mass would be related to the intensification of muscular strength and stimulation of the bone remodeling in the sites pressed by the muscle[2].

Concerning the fat and the lean mass action in the bone mass, their quantification in elderly individuals with osteoporosis can collaborate for the improvement in the treatment of basic pathologies through the institution of physical activity programs which aim to better distribute these compartments.

The determination of the body composition of the elderly requires methodologies and classifications directed to these populations due to specific age body alterations[4]. Moreover, the presence of pathologies which involve alterations in the body compartments also require the utilization of specific methodology.

Among the non-invasive methods for the body composition determination used in elderly population, there are the measurements of the skinfolds thickness and body circumferences, electrical impedance and dual energy X-ray absorptiometry (DXA).

The evaluation of the muscular mass and the body fat through the DXA technique has been appropriate for studies of the body composition[5-6]. It consists of a non-invasive method with a minimum radiation dose (usually lower than 10 μSv), short time execution and appropriate to elderly or sick individuals[7]. The functioning principle is based on the fact that when an X-ray source is placed next to an object, the ray reflected in the opposite side of this object reflects its thickness, density and chemical composition. Thus, the dual emission of X-rays by the energy source allows the quantification of the skeleton sites surrounded by a large quantity of soft tissues, estimated by the difference of attenuation between the bone and the soft tissue[8].

According to Lukaski[9] (1987), the DXA may be considered as gold-standard for the evaluation of body compartments, once it performs the direct measurement of the muscular mass and adipose tissue with precision and accuracy. Nonetheless, the equipment is not available and viable for some field studies due to its high costs.

The skinfolds thickness and skin circumferences measurements are techniques widely used for the body fat and fat-free mass evaluation in several groups of individuals and the subcutaneous fat estimate is reasonably accurate[10]. Despite being a fast measure-

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ment which does not require extremely costly equipments, the body composition estimate through the skinfolds thickness is a technique more prone to measurement errors involving for example, equipment imprecision and inability of the examiner, fact which demands high training from the researchers. Another disadvantage is that great part of the estimate equations of the subcutaneous fat is standardized for healthy young populations. Therefore, the need of studies which enable the utilization of these measurements in differentiated populations has been the target of countless research[8].

Considering the lack of a body fat predictive equation specific to women with osteoporosis and osteopenia in the literature, and that the adequate evaluation of the nutritional status of the elderly is crucial for the establishment of effective prevention therapies, this study had the aim to develop an equation for the estimation of the body fat based on skinfolds thickness measurements having as reference the DXA for this specific population.

METHODOLOGY

Population

Twenty-nine women with age range between 67 and 84 years, seen at the Osteoporosis Clinic in the Rheumatology Division of the Medicine School, of the São Paulo University participated in the study (FMUSP).

All women presented osteoporosis (n = 25) or osteopenia (n = 4) in the two sites evaluated (L1-L4 and proximal femur), according to criteria of the World Health World Organization (WHO)[11]. Women who presented femur fracture confirmed by radiometry evaluation were excluded from the study. The study's protocol was evaluated and approved by the Ethics Committee of the Public Health University (process # 1044) and all participants signed the consent form.

Anthropometry

The skinfolds thickness was measured in order to evaluate the body composition according to techniques described by Lohman *et al.*[12] (1992). A *Harpender* calibrator (British Indicators Ltd, Luton, UK) with 0,1 mm precision and constant pressure of approximately 10 g/mm^2. was used for the measurement of the skinfolds All measurements were performed on the right side of the body in three times and the values mean used for the calculations.

The bicipital and tricipital skinfolds were obtained by the perpendicular skin pinching through the positioning of the calibrator in the mid-arm, determined by the distance between the acromial process of the shoulder and the olecranon (ulna extremity), on the anterior and posterior right arm positions, respectively.

The subscapular skinfold was obtained by the diagonal skin pinching, 1 cm below the posterior extremity of the scapula, positioning the calibrator in a 45º angle following the bone curving.

The suprailiac skinfold thickness was measured through the armpit axis pinching immediately above to the horizontal line of the iliac top and positioning the calibrator in a 45º angle.

The weight and the height were obtained during the DXA, in the Osteoporosis Clinic, on a FILIZOLA® platform digital scale. The Body Mass Index (BMI) was calculated through the division of the weight in kilograms (kg) by the square of the height in meters(m) and classified according to critical indices proposed by Lipschitz[13] (1994), which establishes as eutrophic the 22 to 27 kg/m^2 interval.

The classification of the nutritional status according to the body fat percentage was based on the critical values exposed by Frisancho[14] (1990), in which the normality value for women above 74 years of age is 38% (Percentile 50).

The DXA was performed in the Rheumatology Department of the FMUSP, by a specialized team. The DXA device was used (Hologic QDR-2000) and the mineral density of the lumbar spine (L1-L4; the proximal femur) and the total body were evaluated. The precision coefficient for each of the measurements was respectively 1,3%, 1,5% and 0,6%.

The body composition by the DXA was obtained through the measurement of the BMD of the total body, consisting of the attenuation of the photo electrical peaks emitted by the X-rays source. The estimate of the fat and lean mass without bone tissue content is derived from the attenuation constant of plain fat and boneless lean mass.

Statistical analysis

The Kolmogorov-Smirnov test was initially applied in order to verify whether all variables had normal distribution.

The Pearson correlation coefficient between the total body fat percentage of the DXA and each skinfold (in millimeters) was initially calculated in order to elaborate the equation. In a second phase, a single linear regression model was estimated using the 4 measurements of skinfolds as independent variables, following a decreasing coefficient order (from high to low).

After the equation elaboration, the intraclass correlation coefficient was used for the correlation verification between the body fat indices measured by the DXA and the ones estimated by the skinfolds equation. The *T-Student* test was used in order to compare the mean of the body fat indices obtained by the DXA with those estimated by the proposed equation as well as by the equation by Durnin and Wormersley (1974)[15].

The total error of the equations was calculated according to Lohman *et al.*[12] (1992), through the equation:

$$\text{Total error} = \sqrt{\Sigma\,(y - y')^2 / N};$$

where y = measured value, y´ estimated value. The Bland and Altman[16] (1986) test was used in order to analyze the concordance between the estimated values by the equation and measured by the DXA.

The SPSS program, version 10.0 for W*indows* was used for all analyses.

RESULTS

The descriptive values are presented in table 1. Twenty-five women presented osteoporosis and 4 osteopenia. All women with osteopenia presented T-score below –1,5 in both evaluated sites. The mean age of the women was 75 years. The mean values, both of BMI and body fat, were within the normality limits established. However, separately analyzed according to Frisancho criteria, 55% of the women were classified as eutrophic (22-27 kg/m^2); 21% with low weight (< 22 kg/m^2) and 24% with BMI above 27 kg/m^2. Concerning the body fat percentage, 41% presented values above the percentile 50 for the age and 14% above the percentile 95.

TABLE 1
General characteristics of elderly women with osteoporosis and osteopenia (n = 29)

Variables	Breadth	Mean (SD)
Age (years)	67-84	74,59 (4,36)
Height (cm)	141-161	150,21 (5,75)
Weight (kg)	43-82	56,06 (9,70)
BMI (kg/m^2)	18,63-35,82	24,89 (4,31)
Total fat – DXA (kg)	8,91-44,21	21,25 (8,13)
% body fat – DXA	20,6-54,4	37,87 (8,15)
BMD (T-score L1-L4)	–5,08-0,44	–2,68 (1,13)
BMD (T-score femur)	–3,30-1,04	–2,35 (0,67)

SD, Standard Deviation.

In table 2, the equations obtained through the analysis of the simple linear regression are presented. The independent variables were tested until the definition of the final model. It was observed that, the model including the sum of the suprailiac, biceps and triceps skinfolds could explain up to 72% the variability observed in the body fat percentage determined by the DXA.

TABLE 2
Regression equations for estimation of body fat percentage in women with osteoporosis and osteopenia (n = 29)

Regression equations	R	R^2	P
%BF = 22,599 + 1,079 * (SI)	0,79	0,61	< 0,001
%BF = 21,980 + 0,598 * (SI + BI)	0,82	0,66	< 0,001
%BF = 17,366 + 0,448 * (SI + BI + TR)	**0,85**	**0,72**	**< 0,001**
%BF = 18,552 + 0,315 * (SI + BI + TR + SE)	0,82	0,66	< 0,001

(SI), supra-iliac; (BI), biceps; (TR), triceps; (SE), subscapular.

The body fat values obtained by the DXA and the one estimated by the equation are presented in table 3. No differences between the body fat means determined by the DXA (gold standard) and the ones estimated by the proposed equation in the regression model were observed.

The estimate total error provided by the created equation was 0,77%.

Comparing the body fat in kg according to the equation proposed with the values obtained by the equation by Durnin and Wormersley[15], statistically significant difference was observed, being 21,7 (7,58) kg *vs* 35,1 (4,62) kg; p = 0,009, proposed equation *vs* equation by Durnin and Wormersley, respectively. Moreover, the body fat estimate by the proposed equation was similar to the one found by the DXA [21,8(8,2) kg]; however, there was not statistical difference between them, p = 0,819.

TABLE 3
Relation between the body fat values obtained by the DXA and the estimated by the equation

Variables	Mean (SD)		T Test p	ICC[1]	Total error[2]
	DXA	Skinfolds			
Total body fat (kg)	21,82 (8,25)	21,7 (7,58)	0,819	0,98	0,40
Error breadth					0,00-1,02
Fat percentage	37,87 (8,15)	37,88 (6,96)	0,981	0,92	0,77
Error breadth					0,00-2,25

[1] Intraclass correlation coefficient.

[2] Total error – $\sqrt{\Sigma (y - y')^2 / N}$

The mean values for body fat in percentage and in kilogram estimated by the skinfolds and measured by the DXA were similar. The correlation between the body fat values in estimated percentage by the equation and measured by the DXA presented positive and significant correlation (r = 0,82; p < 0,001) (figure 1).

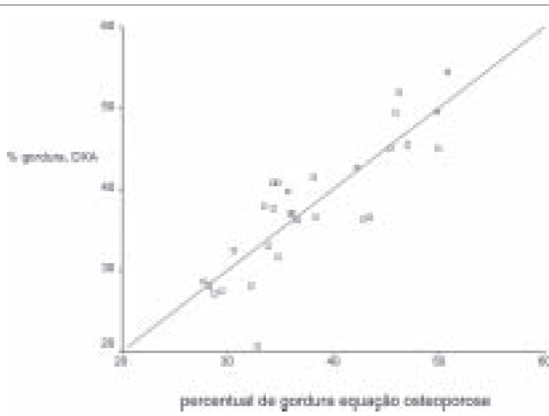

Figure 1 *– Gráfico de correlação entre a percentagem de gordura corporal dada pela DXA e a estimada pela equação proposta*

The plotting of the difference between the means of the standard equation and the one proposed for estimation of body fat in percentage and in kilograms are shown in figures 2 and 3, respectively.

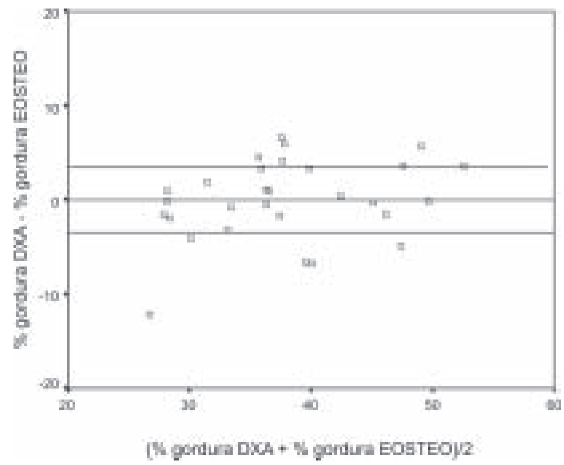

Figure 2 *– Scatter plot do erro padrão estimado entre a média da percentagem de gordura corporal da DXA e da equação proposta*
DXA – Dual energy X-ray absorptiometry
EOSTEO – equation for the body fat estimation of elderly women with osteoporosis and osteopenia

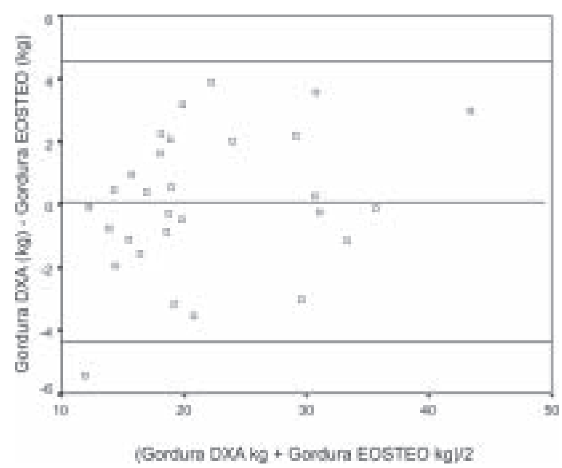

Figure 3 *– Scatter plot do erro padrão estimado entre a média da gordura corporal em quilogramas da DXA e da equação proposta*
DXA – Dual energy X-ray absorptiometry
EOSTEO – equation for the body fat estimation of elderly women with osteoporosis and osteopenia

It is seen in figure 2 that the majority of the points are found within the trustfulness limit determined by the extreme lines of the graph. When the difference between the body fat means in kilograms of the DXA and the one obtained by the proposed equation (figure 3) are observed, the distribution of the points is concentrated so that only one is outside the low limit of two standard-deviations, confirming thus, a good agreement between the equation and the gold-standard.

DISCUSSION

The present study showed that the proposed equation could efficiently predict the body fat percentage in women with osteoporosis and osteopenia.

Highly accurate techniques, such as DXA, suitable as reference methods, many times are not concomitantly applicable to field studies. Thus, several works have tried to reach a consensus regarding different methods of evaluation of the body composition, with the purpose to validate methods which could more easily estimate the percentage of body fat in the population, both in healthy and sick individuals[10,17-18].

Anthropometry is a measuring technique which requires a specialized team so that there is reproducibility and data trustfulness. Besides that, it is usually an economical an viable method for field studies[7,19].

It has been verified that skinfolds thickness measurements tend to overestimate the body fat percentage in overweighed and obese young and middle-aged women, once the body fat increase is basically given by the fat accumulation in the subcutaneous tissue[20].

A problem of this technique when applied to an elderly population relies on the fact that a centralization and internalization of the fat occurs over the years and anthropometry is based on the principle that fat of the subcutaneous tissue is representative of the total fat, being able hence to underestimate the adipose mass in these individuals[7,18-19].

The agreement between the DXA and the skinfolds equation for estimation of body fat percentage in the population in general has been suitable. Nevertheless, the predictive formulas developed for young individuals as well as adults are not valid for elderly individuals[18].

In our study, despite the variation concerning the body fat percentage among women (20,6-54,4% BF_{DXA}), the estimated standard error by the proposed equation was small (0,77% BF) and the determination coefficient was good (r^2 = 0,72; p < 0,001) according to Lohman[12] (1992).

A study conducted by Van der Ploeg *et al.*[21] (2003) in order to generate prediction equations of body fat percentage in men, using nine skinfolds in multiple linear regression, obtained an equation including 6 skinfolds (subscapular; biceps; abdominal; thigh; calf and axillary) with r^2 of 0,89 and standard error of 2,5%.

In the present study, with the measurement of three skinfolds (suprailiac; bicipital and tricipital) it was possible to reach an equation with error below 1%, enabling thus, these measurements of the skinfolds for evaluation of the body composition.

Weight loss in the elderly is common; however, the reduction is not proportional between lean mass and body fat, being the reduction of lean mass higher than the body fat. Consequently, the fat percentage increases[3].

The relation between lean mass and body fat in the BMD has been widely studied[22-24]. The body weight plays a positive effect on the bone mass due to the greater mechanical load of the bone tissue; however, the body fat effect and the lean mass as determinant of the bone mass are still controversial[3]. Some studies demonstrate that the two compartments have similar importance in the bone mass in elderly individuals[22,23]. Concerning post-menopausal women, Douchi *et al.*[22] (1997) showed that the body fat is one of the most important determinant of the BMD.

The basis for the positive effect of the body fat in the bone mass of elderly women is related to factors such as: higher estrogen and leptin production (protecting hormones of the bone mass loss)[25-26]; mechanical effect of the adipose tissue; insulin and growth factors similar to insulin which also play a protection factor in the bone mass; finally the common origin of the osteoblasts and adipocites[25].

Conversely, the high quantity of body fat plays negative effects in the development of diseases such as cardiovascular; obesity and some kinds of cancer, among others. Thus, the exact quantification of body fat in the elderly is important in order to design intervention programs with the purpose to adapt the body compartments.

It was verified that through the Bland-Altman test, the proposed equation is suitable, once the majority of the points were within the reliability limit.

The present study presents some limitations, such as the need to apply the proposed equation in a significant number of women with osteoporosis The low number of participants does not invalid the study, once the estimation of body fat found with the proposed equation showed through the statistical methods to be very similar to the value determined by the gold-standard (DXA).

Therefore, the equation for the body fat estimation in this study contributes to the evaluation of the body composition of elderly women with osteoporosis is conducted with accuracy. Moreover, prevention programs and osteoporosis treatment become possible as well as their efficiency guaranteed.

CONCLUSION

Concerning the present results, the equation resulting from the simple linear regression model for elderly women with osteoporosis from this study was adequate for the body fat estimation in this population.

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