DEVELOPMENT AND VALIDATION OF EQUATION FOR PREDICTING BODY COMPOSITION IN ELDERLY WOMEN

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DESENVOLVIMENTO E VALIDAÇÃO DE EQUAÇÕES PARA PREDIÇÃO DA COMPOSIÇÃO CORPORAL EM IDOSAS

DESARROLLO Y VALIDACIÓN DE ECUACIONES PARA LA PREDICCIÓN DE LA COMPOSICIÓN CORPORAL EN ANCIANAS

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ABSTRACT

Introduction: Body composition assessment (BCA) using anthropometric measurements (AM) is used to monitor the nutritional and health status of the elderly. As predictor variables, MAs must be valid, practical, and quick, as they favor adherence and avoid possible resistance and embarrassment on the part of those being assessed and being minimally invasive. Objective: To develop and validate equations using accessible and minimally invasive anthropometric measurements for BCA in elderly women. Methods: 100 women (68.1±6.15 years) were randomly assigned to two groups: validation (n=40; 68.1±6.15 years); and estimation (n=60; 68.4±6.70 years). DXA was selected as the criterion measure, and MAs (body mass, height, skinfolds, circumferences) were selected as predictor variables. Means were compared using the paired Student's t-test; correlations were verified using Pearson's r-test; equations using Multiple Linear Regression. The level of agreement between the groups' results was checked using the Bland-Altman technique. Results: Two equations developed and tested (E3 and E4) met the validation criteria as they showed adequate correlation coefficients (E3: r=0.73; E4: r=0.70), low constant errors (E3: EC= -0.56; E4: EC=-0.90), total error (E3: ET=3.22; E4: ET=3.06) lower than the Standard Error of Estimate (E3: EPE=3.24; E4: EPE=3.21), indicating no statistically significant difference between the two BCA techniques observed (p>0.05). The Bland-Altman technique showed good agreement between the results of the two techniques. Conclusion: Two were validated: E3 (%Gdxa= - 41.556 + 4.041(BMI) + 0.165(DcCox) - 0.440(CircCox) + 0.269(CircQuad) - 0.053(BMI)^2); and E4 (%GdxaE4= 15.329 + 1.044(BMI) -1.055(CircAbra) + 0.282(CircQuad) + 0.164(DcCox) - 0.262(CircCox)). Notably, the small number of measurements were located in areas of the body that are easily accessible and have little body exposure, which minimizes possible embarrassment and favors adherence by the elderly. ***Level of Evidence IV; Correlational study to build a predictive equation.***

Keywords: Body Fat Distribution; Aging; X-Rays; Anthropometry.

RESUMO

Introdução: A avaliação da composição corporal (ACC) com auxílio das medidas antropométricas (MA) é utilizado no acompanhamento do estado nutricional e de saúde das populações idosas. As MAs como variáveis preditoras, devem ser válidas, práticas e rápidas, pois favorecem a adesão e evitam possíveis resistências e constrangimento das avaliadas, além de minimamente invasivas. Objetivo: Desenvolver e validar equações utilizando medidas antropométricas de fácil acesso e minimamente invasivas, para ACC de idosas. Métodos: 100 mulheres (68,1±6,15 anos) distribuídas aleatoriamente por dois grupos: validação (n=40; 68,1±6,15 anos); estimativa (n=60; 68,4±6,70 anos). Como medida critério selecionou-se a DXA, como variáveis preditoras as MAs (massa corporal, estatura, dobras cutâneas, circunferências). As médias foram comparadas com o teste t de Student pareado; as correlações verificadas com o teste r Pearson; as equações com a Regressão Linear Múltipla. O nível de concordância entre os resultados dos grupos foi verificado com a técnica Bland-Altman. Resultados: Duas equações desenvolvidas e testadas (E3 e E4) atenderam aos critérios de validação, pois, apresentaram coeficientes de correlação adequados (E3: r=0,73; E4: r=0,70), erros constantes baixos (E3: EC= -0,56; E4: EC=-0,90), erro total (E3: ET=3,22; E4: ET=3,06) menores que o Erro Padrão de Estimativa (E3: EPE=3,24; E4: EPE=3,21), indicando não existir diferença estatisticamente significativa entre as duas técnicas de ACC observadas (p>0,05). A técnica Bland-Altman demonstrou boa concordância entre os resultados das duas técnicas. Conclusão: Duas foram validadas: E3 (%Gdxa= - 41,556 + 4,041(IMC) + 0,165(DcCox) – 0,440(CircCox) + 0,269(CircQuad) – 0,053(IMC)^2); e E4 (%GdxaE4= 15,329 + 1,044(IMC) -1,055(CircAbra) + 0,282(CircQuad) + 0,164(DcCox) – 0,262(CircCox)). Destaca-se o fato do reduzido número de medidas situarem-se em áreas corporais de fácil acesso e de pouca exposição corporal, que minimizam possíveis constrangimentos e favorecem a adesão das idosas. **Nível de Evidência IV; Estudo correlacional para construção de equação preditiva.**

Descritores: *Distribuição da Gordura Corporal; Envelhecimento, Raios-X, Antropometria.*

RESUMEN

Introducción: La evaluación de la composición corporal (ECC) mediante medidas antropométricas (MA) se utiliza para monitorizar el estado nutricional y de salud de las personas mayores. Las MA, como variables predictoras, deben ser válidas, prácticas y rápidas, ya que favorecen la adherencia y evitan posibles resistencias y vergüenzas por parte de *los evaluados, además de ser mínimamente invasivas. Objetivo: Desarrollar y validar ecuaciones utilizando medidas antropométricas de fácil acceso y mínimamente invasivas para la ECC en mujeres de edad avanzada. Métodos: 100 mujeres (68,1±6,15 años) asignadas aleatoriamente a dos grupos: validación (n=40; 68,1±6,15 años); estimación (n=60; 68,4±6,70 años). Se seleccionó la DXA como medida criterio, y las MA (masa corporal, estatura, pliegues cutáneos, circunferencias) como variables predictoras. Las medias se compararon mediante la prueba t de Student emparejada; las correlaciones se comprobaron mediante la prueba r de Pearson; las ecuaciones mediante Regresión Lineal Múltiple. El nivel de concordancia entre los resultados de los grupos se comprobó mediante la técnica de Bland-Altman. Resultados: Dos ecuaciones desarrolladas y probadas (E3 y E4) cumplieron los criterios de validación, ya que mostraron coeficientes de correlación adecuados (E3: r=0,73; E4: r=0,70), errores constantes bajos (E3: EC= -0,56; E4: EC=-0,90), error total (E3: ET=3,22; E4: ET=3,06) inferior al error estándar de estimación (E3: EPE=3,24; E4: EPE=3,21), lo que indica que no se observaron diferencias estadísticamente significativas entre las dos técnicas de ECC (p>0,05). La técnica de Bland-Altman mostró una buena concordancia entre los resultados de las dos técnicas. Conclusión: Se validaron dos: E3 (%Gdxa= - 41,556 + 4,041(IMC) + 0,165(DcCox) - 0,440(CircCox) + 0,269(CircQuad) - 0,053(IMC)²); y E4 (%GdxaE4= 15,329 + 1,044(IMC) -1,055(CircAbra) + 0,282(CircQuad) + 0,164(DcCox) - 0,262(CircCox)). Es de destacar que el reducido número de mediciones se localizaron en zonas del cuerpo de fácil acceso y con poca exposición corporal, lo que minimiza posibles situaciones embarazosas y favorece la adherencia por parte de los ancianos.* ***Nivel de Evidencia IV; Estudio correlacional para construir una ecuación predictiva.***

Descriptores: *Distribución de la Grasa Corporal; Envejecimiento; Rayos X; Antropometría.*

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INTRODUCTION

Although the timing, speed, and severity of the changes in body composition (BC) during the aging process may differ between people, they will occur in all of them, whether healthy or athletes.[1]

Changes in BC throughout life are strictly related to health status. The increase in fat mass and the decrease in muscle mass and strength, a phenomenon known as sarcopenia, are typical of aging and are associated with an increase in age-related pathologies, a decline in functionality, an increase in the risk of falls, hospitalizations, morbidities, and mortality. For these reasons, the study of BC is so important because it allows changes to be monitored, preventing pathologies and age-related limitations.[2] Because it allows changes in fat mass (FM) and lean mass (LM) to be monitored, the assessment of BC in the elderly is an important resource for monitoring nutritional status, controlling various metabolic diseases, and maintaining health and quality of life.[1,3] The above applies to both sexes; however, since elderly women have less absolute muscle mass when compared to men of the same age, for females, BC assessment can bring additional advantages in the sense of predicting future functional limitations.

Several laboratory methods are used as the 'gold standard' and as a yardstick for other tests to assess BC (Dual Energy X-ray Absorptiometry, Computed Tomography, and Hydrostatic Weighing, among others). However, although they have greater validity and accuracy, in addition to only allowing individual approaches, these techniques are expensive, require high levels of cooperation from those being assessed, and require specialized technicians and laboratory environments.[2,4-6]

Due to its validity and characteristics, Dual Energy X-ray Absorptiometry (DXA) has been increasingly used as a criterion measure for assessing BC.[7,8] However, due to the characteristics described above, this test is expensive for most people and makes it difficult to use in population studies.[9] Given the above, the search for and need for valid, simpler, and less expensive tests has become essential for clinical practice and studies with large populations.[4]

In this direction, anthropometric measurements (AM) such as body mass, height, skinfolds, and circumferences have been increasingly used to construct equations to predict BC in different populations.[10-12] Despite the possibility of using such equations to assess BC, it is important to consider that their generalized use is neither automatic nor advisable. In other words, the predictive equations must respect the characteristics of the population studied, considering, among other things, the different age groups, ethnicities, cultural habits, genders, and levels of physical fitness. The widespread use of predictive equations can make their validity unfeasible.[13]

When using predictive equations to assess BC in elderly Brazilian women, the number of validated equations available is still insufficient. Most validation studies of this type carried out in Brazil used people from the South,[14-16] and Southeast[17,18] regions of the country as their samples. Therefore, during the cross-validation process, it is not uncommon to see significant differences between the results of the CCA in different regions.

Given the above, the main objective of this study was to test, develop, and validate anthropometric equations capable of assessing the BC of elderly women living in the municipality of Maceió/AL. Secondly, the least invasive anthropometric measurements were evaluated and selected for the equations.

MATERIALS AND METHODS

The study sample consisted of 100 elderly women (68.1±6.15 years old) selected from leisure physical activity programs offered by 22 institutions for the elderly (ITI) in the municipality of Maceió. All the participants signed an informed consent form (ICF) by the recommendations of Resolution 466/12 of the Brazilian National Health Council for research involving human beings. All project stages were approved by the Human Research Ethics Committee of the Universidade Federal de Alagoas (protocol No. 23065.020769/2009-31).

The elderly women who made up the sample were randomly assigned to two different groups: the validation group - GV (n=40; mean/DP= 68.1±6.15 years) and the estimation group - GE (n=60; mean/DP= 68.4±6.70 years).

Data collection

Anthropometric measurements were taken at various times in the 22 institutions investigated. A LANGE adipometer (Beta Technology, Santa Cruz, CA, USA) was used to measure skinfolds (SC): thigh, leg, abdomen, triceps, biceps, mid-axillary, and supra-iliac; for circumference measurements (CM): brachial, forearm, abdominal, waist, hip, thigh and leg circumferences, a steel tape measure five millimeters wide and two meters long (Sanny - *American Medical do Brasil*, Ltda, São Bernardo do Campo/SP, Brazil) was used; height was measured with *Seca* brand portable stadiometers *(Baystate Scale & Systems*, USA) and body mass with the aid of Tanita brand portable digital scales (Mod: UM 080W *Scale Plus Body Fat Monitor with Body Water - American Medical do Brasil,* Ltda, São Bernardo do Campo/SP, Brazil).

Measurements of WC and HC were taken as recommended by Pollock and Jackson.[19] BMI (ratio of body mass to height) was obtained in kg/m^2.

A Lunar Prodigy Advanced series DPX-YZB/2099 scanner (Madison, WI) was used to measure the DXA, and the BC variables were calculated using the software provided by the manufacturer (version 3.0). The equipment was calibrated daily by a specialized technician from an imaging clinic in Maceió/AL, following the manufacturer's recommendations.

Statistical Analysis

The sample was characterized using descriptive statistics, using the arithmetic mean *(X)* as a measure of central tendency and the standard deviation (SD) as the main measure of dispersion. The normality of data distribution was assessed using the *Kolmogorov-Smirnov* test, and the homogeneity of variances using the Levene test.

The equations were developed using the stepwise-multiple regression technique, and the paired student's *t-test* was used to compare the means of % fat assessed by DXA and the equations developed.

To carry out the cross-validation, in addition to Pearson's r correlation coefficient and the paired student's t-test, the total error (TE), the constant error (CE), and the standard error of estimate (SEM) were also calculated. All statistical calculations were carried out on the two groups separately.

The Bland-Altman test was used to analyze the agreement between the body fat values estimated by the equations developed and those measured by DXA. Limits of agreement were defined with a mean standard deviation of ±1.96 between the equation and the standard test and a 95% confidence interval.

All statistical tests were done using the *Statistical Package for the Social Science,* version SPSS® 20.0 (Chicago, IL, USA).

Ethics Statement

The Universidade Federal de Alagoas (UFAL) ethics committee approved the research under protocol number 020769/2009-31.

RESULTS

Table 1 shows the anthropometric characteristics of the total sample (AT) and the estimation (GE) and validation (GV) groups.

Table 1 shows the characteristics of the subjects in the validation (GV) and estimation (GE) groups.

To develop the regression equations, in addition to body mass (BM), height (HGS), and BMI (kg/m^2), circumference measurements were used: brachial (CircBra), forearm (CircAbra), thigh (CircCox), leg (CircPer), abdomen (CircAbd), waist (CircCint) and hip (CircQuad). Some skinfold measurements were also used: triceps (DcTri), biceps (DcBi), subscapular (DcSE), mid-axillary (DcAx), abdominal (DcAbd), supra-iliac (DcSI), thigh (DcCox) and leg (DcPer).

In addition, as proposed by Prothro and Rosenbloom,[20] in an attempt to verify the best correlations, all the measures were evaluated in their simple form and squared (X^2) and cubed (X^3).

Age and height were excluded from the equation models because they had the lowest correlations with DXA. The measurements of WC, BMI, circumference, skinfolds, and some combinations of skinfolds and circumference showed significant correlations and were used to develop the regression equation models.

In developing the equations, eight linear regression equation models were obtained. All models were subjected to validation analysis using recommended criteria.[20, 21]

Of the equations developed, four were discarded (E1, E6, E7, and E8) as they showed statistically significant differences ($p<0.05$) for the fat percentage (%F) averages when compared to the criterion test (DXA). They also had a multiple correlation coefficient *(Pearson's r)* of less than 0.70. The remaining four equations, E2, E3, E4, and E5, were submitted to the cross-validation stage in the validation group (Tables 2 and 3). As the correlation coefficients were lower than recommended (*r=0.*64) and the total error was greater than the standard estimation error, equations E2 and E5 were discarded. Therefore, at the end of the validation process, only two equations, E3 and E4, met all the validation criteria and were recommended for use.

Figures 1 and 2 show the dispersions between the differences in mean %G measured by DXA and those estimated by equations E3 and E4 obtained from the dispersion diagram.

After all these validation stages, two anthropometric equations were validated for use because they were simple to apply and had high predictive power: E3: %Gdxa= - 41.556 + 4.041 (BMI) + 0.165 (DcCox) - 0.440 (CircCox) + 0.269 (CircQuad) - 0.053 (BMI)^2; and E4: %GdxaE4= 15.329 + 1.044 (BMI) -1.055 (CircAbra) + 0.282 (CircQuad) + 0.164 (DcCox) - 0.262 (CircCox).

Table 1. Descriptive characteristics of the sample used in the study.

Variable	Total sample (AT)		Estimation group (EG)		Validation Group (GV)	
	n = 100		n = 60		n = 40	
	X ± Dp	mv – MV	X ±Dp	mv – MV	X ± Dp	mv – MV
Age	68.1±6.15	60.0-89.7	68.4±6.70	60.0-89.7	67.6±5.26	60.0-79.5
MC (Kg)	63.7±9.27	45.5-90.0	64.3±9.67	46.0-90.0	62.9±8.69	45.5-88.7
Est (cm)	150.2±6.4	1.34-1.66	150.7±6.7	1.34-1.66	149.6±5.9	1.35-1.61
BMI Kg/m2	28.2±3.85	19.1-38.5	28.3±3.91	21.9-38.5	28.1±3.81	19.1-36.6
%G DXA	42.2±5.42	27.7-53.2	42.4±6.06	27.7-53.2	41.9±4.37	34.1-50.4
MGDXA(Kg)	26.1±6.37	14.0-42.9	26.5±6.80	14.0-42.9	25.5±5.69	14.9-42.9
MMDXA(Kg)	35.1±4.17	27.1-48.5	35.3±4.43	27.1-48.5	34.8±3.78	28.4-44.2

X = arithmetic mean; n: sample; MV: highest value; mv: lowest value; SD: standard deviation; MC: body mass; Est: height; BMI: Body mass index; %g DXA: fat percentage measured by DXA; MGDXA: fat mass measured by DXA; MMDXA: lean mass measured by DXA. (Maceió, 2011).

DISCUSSION

This study aimed to develop and validate new anthropometric equation models for assessing BC, specifically for elderly Brazilian women.

Table 2. Best equation models developed in this study and validated internally in the validation group (GV).

Equations	R	T	R	R^2	EPE
	p-value	p-value			
E2	.693**	2.127	.693	0.48	3.30
	.001	.040			
E3	.732**	0.952	.732	0.53	3.24
	.001	.347			
E4	.703**	1.645	.703	0.49	3.21
	.001	.108			
E5	.624**	.608	.624	0.38	3.21
	.001	.547			

Pearson's R ($p< 0.05$); paired t-test ($p> 0.05$); R: correlation coefficient; R^2: coefficient of determination; EPE: Standard error of estimate. (Maceió, 2011).

Table 3. Comparison of the Total and Constant Error with the Standard Error of Estimate.

Equations	Constant Error	Total Error	Standard Error estimate
E2	- 1.2012	3.72	3.30
E3	- 0.5672	3.22	3.24
E4	- 0.9078	3.06	3.21
E5	- 0.3951	4.07	3.21

Total error $=\sqrt{\sum(y1-y2)^2 / n}$; Constant error= ((%Gm) - (%Ge)); Standard error of estimate = s$\sqrt{1 - r^2}$; Y1= % fat measured by DXA; Y2= % fat estimated by the equations developed; n = Sample %Gm = Average fat percentage measured by the equations; %Ge = Average fat percentage estimated by DXA; S = standard deviation; r2= coefficient of determination. (Maceió, 2011).

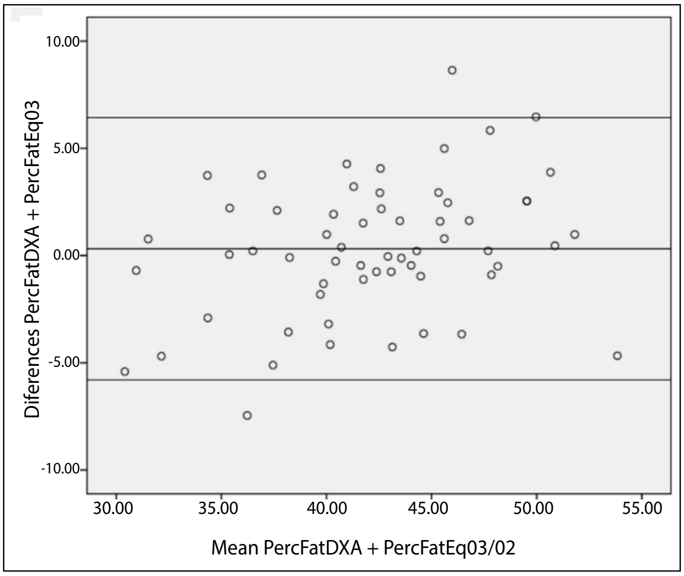

Figure 1. Scatterplot of Estimated error for Equation E3.

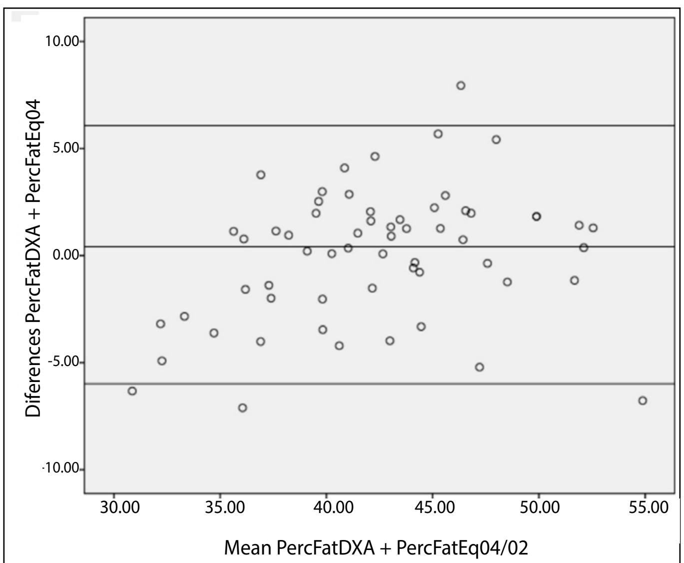

Figure 2. Scatterplot of Estimated error for Equation E4.

Eight equation models were obtained after analyzing the correlations between the MAs that could serve as independent variables for predicting BC. However, after evaluating the proposed validation criteria, two equations, E3 and E4, were considered valid.

E3 and E4 had moderate coefficients of determination (R^2), explaining 53.39% and 50.49% of the BC predicted by DXA, respectively. Rech et al,[14] using circumference and skinfold measurements, validated two equations with higher R^2 values (0.77 and 0.81) than those observed in this study; however, in addition to using participants from the southern region of the country, the proposed equations had higher EPEs (3.51 and 3.81) than those observed in the equations in this study. Heyward and Stolarczyk[22] note that when evaluating the predictive capacity of a regression equation, the size of the EPE is more important than the correlation and determination coefficients, as these can be highly affected by the size and variability of the sample and do not represent measures of accuracy between two means.

Among the independent variables used in the two equations validated in this study, BMI was the variable that correlated best with DXA (r=0.75). The same was observed in other studies[11,23,24] which also found a strong correlation between BMI and CSA.

One resource used to try to increase the correlation coefficient of some variables in equation,[20] is to raise the results of some measurements to some power. BMI^2 was, therefore, also included in E3. It should be noted that the inclusion of this measure increased the percentage of variance explained, consequently increasing the accuracy in predicting BC.

Salamat et al[25] suggest that to increase the predictive power of BMI, combining it with other anthropometric measures is important. This study found that BMI correlated well with hip (r=0.763) and thigh (r=0.735) circumferences and also with thigh skinfold (r=0.693). Therefore, it was found that when using these measures in the same model, the correlation coefficient increased while the EPE decreased, increasing the predictive power of the equation.

The main advantages of using equations that use anthropometric measurements and BMI as independent variables lie in that these measurements are easy to measure, do not require sophisticated equipment and are not invasive.

Another important point is that several studies have validated equations for predicting BC using skinfold measurements as independent variables.[15,24,26] Corroborating these studies about the use of skinfolds, DcCox was the measurement that individually correlated best with DXA *(r=0.*42).

The use of anthropometric equations is a possible substitute for laboratory tests. However, for this purpose, it is important that the equation uses easy-to-access and measure measures and has a small number of variables to facilitate calculations, especially in studies with elderly populations. Concerning the number of independent variables used in this study, it should be noted that neither of the two validated equations used more than five measures.

In contrast to the results presented here, several studies[9,14,24,27,28] have validated regression equations to predict BC in the elderly using an equal or greater number of independent variables. However, the variables used in the models proposed in this study (skinfolds, circumferences, weight, and height) are easy to measure and also have low measurement errors (intra or inter-assessor).

CONCLUSION

The study has successfully validated two-equation models that use anthropometric measurements to predict body composition in elderly women. It has been established that the proposed measurements are taken in easily accessible areas of the body, requiring only a minimum number of measurements. This minimally invasive approach is particularly beneficial for the elderly population.

All authors declare no potential conflict of interest related to this article

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