Body fat percentage prediction in older adults: agreement between anthropometric equations and DXA

Authors:

Erika Aparecida Silveira[1,5], Larissa Silva Barbosa[2], Matias Noll[1,3], Hudson Azevedo Pinheiro[4], Cesar de Oliveira[5]

Affiliations:

[1] Faculty of Medicine, Health Sciences Graduate Program, Federal University of Goiás

[2] Pontifical Catholic University of Goiás

[3] Goiano Federal Institute

[4] Euroamerican University Centre

[5] Epidemiology & Public Health Department, University College London

*** Corresponding author:**

Dr Erika Aparecida Silveira
Associate Professor
Faculty of Medicine
Supervisor at the Health Sciences Graduate Program
Severe Obesity Study Group
Federal University of Goiás
Email: erikasil@terra.com.br

Abstract

Background: It is difficult to measure body fat percentage in clinical settings. Equations using anthropometric measures are more feasible and can be used to estimate body fat. However, there is a need to analyze their accuracy in older adults. Our study aims to validate the use of anthropometric equations to estimate body fat percentage in older men and women.

Methods: This study evaluated data from 127 Brazilian individuals aged between 60 and 91 years. Weight, height, skinfold thickness and waist and hip circumferences were measured. Seventeen anthropometric equations were tested using the crossed validity criteria suggested by Lohman and the graph analysis proposed by Bland and Altman and by Lin was also performed. The gold-standard method for comparing the anthropometric equations was the dual-energy absorptiometry X-ray (DXA).

Results: The average body fat percentage was 30.2±8.6% in men and 43.4±7.9% in women ($p < 0.001$). In men, the equations which used skinfold thickness presented amplitude of 11.48%, while in women, amplitude's constant error (CE) was 22.88%. The equations based on circumferences and BMI presented CE variation from -5.3% to 29.68% on the estimation of body fat percentage, which means that a same male individual can have the total body adiposity diagnosed with 34.98% of variation, depending on the selection of the employed equation. For women this CE variation was 12.44%.

Conclusion: Overall, all the equations yielded different results from the gold standard. However, the best equations for male were the one of Lean et al. (1996), which uses the waist circumference, and for women the one of Deurenberg et al. (1991), developed from the body mass index. The need of developing specific equations for older adults still remains, since even the two best equations showed considerable limitations on predicating body fat percentage.

Keywords: anthropometric measures, body composition, body fat percentage, Dual-Energy X-Ray Absorptiometry, Body Mass Index, ageing

Introduction

Overweight and obesity rates are worryingly increasing and this has direct implications on public health and poor health outcomes (1,2). Body fat amount and distribution in older adults increases their risk of coronary heart diseases, hypertension and diabetes mellitus (3,4). There are several methods to evaluate body composition, varying from the most sophisticated ones, such as computed tomography (CT) scan, magnetic resonance imaging (MRI), dual-energy X-ray absorptiometry (DXA), to the simpler ones which estimate it indirectly, such as skinfolds (SF) thickness and circumferences (5,6).

CT scan, MRI and DXA are considered reference methods to estimate the body fat in older adults. However, their use is limited due to the high costs of equipment, the need for qualified professionals, becoming, many times, not feasible to use in several clinical and public health settings (7). In turn, anthropometry is the most used method to estimate the body fat, due to its low-cost and easy applicability, by both researchers and ambulatory practice (8).

The SF thickness measures can estimate the subcutaneous fat in certain parts of the body in accurate way. However, problems such as the redistribution of subcutaneous fat, selection of the appropriate equation and the measurement technique are important issues and can limit accuracy in older adults (8–10). The equations developed using anthropometric measures such as weight, height and waist and hip circumference, in turn, are cheap, non-invasive, easily applicable and show smaller measurement error when compared to the ones using SF (9,10).

Nevertheless, the application of the anthropometric equations in other populations other than those from the origin sample requires validity analysis. To select more appropriate equations, factors such as age, gender, ethnicity and body fat distribution need to be taken into account. Ideally, the features of the population to be evaluated should be similar to the ones from the sample used on the validation process of the selected equation (11). It is necessary that body fat percentage is accurately diagnosed, however studies exploring the validity of prediction equations in older adults are very scare (12,13). Thus, the purpose of this study was to analyze the validity of anthropometric equations to estimate the body fat in older men and women compared to a gold standard method i.e. DXA.

Methods

Study population

This study used data from the cohort study known as Projeto Idoso/Goiânia (Elderly Project/Goiânia). This study was approved by the Committee of Ethics in Research of Federal University of Goias (Protocol nº 031/2007). A more detailed description of the project's methodology can be found elsewhere (14,15).

The sampling was performed in multiple stages with the Sanitary Districts of Goiânia considered the primary units to randomly select the sample. At the first stage, 418 older adults were interviewed, representing the elderly population using the primary health care (PHC) provided by the city, from whom random assortment proportional to BMI rates found in the origin population was done in order to set up a subsample of 132 elders. DXA and other exams were performed in this subsample.

The number of older adults from the subsample was established taking into account a sample size of at least 100 individuals, necessary for the use of Bland and Altman statistics analysis (16). Based on the correlation coefficient, considering a two-tailed significance level (α) = 0.05, β = 0.05 (power of 95%) and an expected correlation coefficient of 0.35, the number of individuals necessary for a validation study would also be 100 (17). Predicting losses and refusals, we increased the sample size in 25%.

Therefore, the present study was conducted with a sample of 127 older men and women, after further excluding five individuals from the subsample i.e. outliers. The outliers were identified, initially, graphically which was next confirmed by the Grubbs test. This approach was used to increase the quality of the equations. After removing non-standard values, the distribution of points in the graphs improved greatly, being close to zero, thus providing higher quality to the equations presented in this study.

Inclusion and exclusion criteria

The inclusion criterion was subjects aged 60 or older, who attended the appointment at the ambulatory in the PHC network twelve months prior to data collection. The exclusion criteria were: institutionalized elderly; disabling diseases which prevent them from getting out the bed or walk around; presence of partial or total amputation that would prevent the anthropometric data collection; pacemaker holders or holders of any type of metal in the body; incapacity of answering the questionnaire due to, for example, severe deafness and muteness. In this latter case, a caretaker could provide the answers.

Measurements

The participants were contacted by telephone and informed about the preparation necessary to perform the ~~electrical bioimpedance (BIA)~~ DXA, and also about the schedule to attend the clinic for it and all the anthropometric measures. On this same day, a standard and previously tested questionnaire was applied by duly trained interviewers. All the evaluations were performed on the same day, in the morning period.

For the identification of the anatomic spots, procedures according to Lohman *et al* (18) were used. Previously to data collection, aiming at the improvement of the execution of techniques and the assurance of higher accuracy of the anthropometric measures, a standardization to calculate the technical error of measurement was performed (19).

Weight and height measures were taken according to Gordon *et al* (20), using an electronic, digital, portable scale Tanita, with capacity for 150 kg and accuracy of 100 g and an inelastic and inextensible measuring tape, with extension of 2.00 m, 2 cm width and accuracy of 0.1 cm and a wood set-square. From these measures, the value of the body mass index (BMI) was obtained. The waist (WC) and the hip circumferences (HC) were measured through an inelastic and inextensible measuring tape, 7 mm width and accuracy of 0.1 mm (21). The mean values of both WC and HC measures were taken into account.

For SF thickness measures, Lange® body caliper was used with constant pressure of 10 g/mm^2 in contact surface and accuracy of 1 mm (22). Evaluations of different sites were performed in series and successively, adopting as final value the mean of three measures. To perform the anthropometric measures, participants wore light clothes or underwear, without shoes, did not hold any object in the pockets, hands or head. All the anthropometric measurements were performed by the same trained evaluator who had more than five years' experience in clinical and research thickness measurements.

The body fat percentage (BF%) was obtained through DXA with full body scanner, Lunar® (model DPX – MD PLUS), software version 7.52.002 DPX-L and the device calibrated daily (23). The participants were using light clothes, were barefoot, with no earrings, rings, dental bridges and other types of metal materials.

From the anthropometric measures, the BF% was estimated through seventeen equations. The anthropometric equations analyzed in the present study were selected according to: 1- age, 2- lower standard error of the estimate (SEE) on their development, 3- the best applicability in the elderly population, and 4- being the most mentioned in the literature and the easiest to obtain (Table 1). Considering that most of the anthropometric equations predict corporal density (D) values in g/mL, these values were converted into relative body fat using the Siri equation (24).

Statistical analysis

Initially, the normality of the variables was verified through Shapiro-Wilk test. The descriptive data were expressed as mean, standard-deviation, median, minimum and maximum values.

To analyze the crossing validity of the anthropometric equations compared to the DXA on the BF% estimation, procedures suggested by Lohman (18) were adopted. The Student's t test for paired samples was used to compare the estimated measures (equations) to those obtained from DXA. Pearson's linear correlation coefficient (r); analysis of the standard-deviation; analysis of constant error (CE), which represents the difference between the estimated and measured values; and the SEE, which represents the expected error for the equation analyzed regarding the gold standard were also performed (18).

The equations were considered valid when did not present statistically different means from the ones obtained through the gold standard i.e. DXA; when presented $r > 0.79$; and values of CE and SEE lower than 3.5%, in both men and women. Lohman (25) suggests the following stratification for the SEE: < 2.0% for being qualified as ideal; from 2.0 to

2.4%, as excellent; from 2.5 to 2.9%, as very good; from 3.0 to 3.4%, as good; from 3.5 to 3.9%, as fairly good; from 4.0 to 4.4%, as weak and, at last, ≥ 4.5%, as not recommended.

The graphical analysis of Bland and Altman (26) and the concordance correlation coefficient (CCC) (27) were also used to evaluate the concordance between the BF% estimated by the anthropometric equations and the one measured by DXA.

According to Bland and Altman (26) the method that presented concordance is the one which has the smallest mean difference between the tested method and the gold standard, and the closer it is to the equality line (line zero), the better is the concordance between tests. The parallel continuous lines indicate confidence intervals (CI 95%) of the mean differences and they allow the checking of the statistic similarity in case the minimum and maximum 95% CI start from a negative number to a positive one, crossing the zero or equality line.

On the other hand, the CCC combines precision and accuracy to establish if observations significantly deviate from the perfect concordance line (45°). When the value is equal to one, it means that the regression line is exactly over the perfect concordance line. Excellent concordance was established as CCC > 0.90; satisfactory concordance, as CCC from 0.60 to 0.90; and unsatisfactory concordance, as CCC < 0.60. Data analyses were done in STATA/SE program version 12.

Results

The study's sample comprised 127 participants aged from 60 to 91 years. Around 52% (n=66) of the sample were 60 to 69 years old and considered as a group of younger older adults. In women, that age range was the predominant (57%), while most of the men (46%) presented age varying between 70 and 79 years.

All the variables presented a normal distribution (p>0.05). It was observed that there was a significant difference (p<0.05) for all the anthropometric and body composition variables between genders, except for WC. Men presented higher WC means whereas women presented higher BMI values, all the SF and BF% (Table 2).

The errors associated to the seventeen different equations which estimate the BF% from different anthropometric measures were analyzed. In men, the equations which used SF presented amplitude (CE) of 11.48%, while in women, the CE amplitude was 22.88%. The equations based on circumferences and BMI presented CE variation from -5.3% to 29.68% on the estimation of the BF%, which means that a same male individual can have the total body adiposity diagnosed with 34.98% of variation, depending on the selection of the employed equation. For women, in turn, this CE variation was 12.44% (Table 3).

Among the equations based on SF, the one of Visser *et al* (28) was the only one similar to DXA ($p>0.05$), presenting an agreement percentage (%C) = 51%, that is, around 51% of older men would have their body fat measured in an accurate way. This equation presented SEE of 3.82% considered as reasonably good according to Lohman (25) (Table 3).

In women, the equation of Visser *et al* (28) was also the only one similar to DXA, presenting concordance of 42.7% with the gold standard, CE of 1.24% and a trend to overestimate values. Besides, the SEE was considered not recommended according to the validation criteria (29) (Table 3).

Regarding the equations based on BMI and circumferences, the ones that did not differ from the gold standard (DXA) in men were those of Lean *et al* (30) and of Deurenberg *et al* (31). The equation of Lean *et al* (32) had a concordance of 58.8%, underestimating the BF% by 0.47%. In turn, the one of Deurenberg *et al* (31) which is based on BMI and age, presented CE of 0.69% and SEE of 4.71%, and, therefore, not recommended as validation criterion according to Lohman (18). For women, only the equation of Deurenberg *et al* (31) did not differ from BF% measure by DXA ($p>0.05$), overestimating BF% by 0.45% and agreeing in 58.7% with the gold standard; therefore, 58.7% of women would have their body fat accurately estimated (Table 3).

The other analyzed equations, in both genders, presented statistically significant differences when compared to the values measured by DXA, besides presenting CE and SEE which also did not meet the validation criteria (25), although some presented high correlation values.

According Bland and Altman (26) technique, no equation was considered excellent (CCC > 90), which can also be observed by the wide limits of agreement (LA). However, some equations were satisfactory (six equations for men and four for women), presenting CCC ranging from 0.60 to 0.90 and respective mean differences and smaller LA than others (Table 4).

Only the equations with similar results to the mean obtained with DXA were analyzed regarding the dispersion of scores (Figure 1). In Figure 1, it can be observed that the equation from Visser *et al* (28), for both genders, overestimated the inferior values and underestimated the superior values related to BF% measured by DXA, so that all Lin graphs built were the ones which presented a bigger distance from the perfect concordance line.

From the evaluated equations in men, the one which presented the best concordance with DXA was the one from Lean *et al* (32), which presented the lowest mean difference (0.47%) and CCC = 0.85, underestimating the BF% of men in less than 0.5% (Figure 1a). Among women, it was verified that the equation of Deurenberg *et al.* (31) was the one which presented the lowest mean difference (0.45%) and CCC = 0.81 (Figure 1b).

Discussion

In the present study, overall, all the anthropometric equations produced different results from the gold standard i.e. DXA. However, the best equations were the one of Lean *et al* (32) which use the WC for men and, for women, the one of Deurenberg *et al* (31), developed from the BMI. Our results showed gender differences on anthropometric measures and BF%, since women presented higher BMI, SF and BF%. Corroborating with our findings, Rech *et al* (10) found that older men presented higher weight, height, fat free mass and lower BF%.

The tested equations presented CE ranging from -17.42 to 29.68% in relation to the gold standard, showing that a same participant can be diagnosed with a wide variation according to their total body adiposity, depending on the selected equation to estimate the

BF%. The bias among estimations (SF and~~BIA,~~ DXA) ranges according to the prediction equation, which is corroborated by other studies (10,33).

In the present study, the only equation that presented a mean of BF% not statistically different from DXA was the one of Visser *et al* (28), for both genders. However, this equation presented unsatisfactory concordance (CCC = 0.53 in men and CCC = 0.46 in women) and low accuracy, so that, at the end of the analysis, it was not classified as a better BF% prediction equation. Similar results were also found in a study performed with older Brazilian adults (34,35), in both genders, and it was observed a trend of BF% overestimation when the Visser *et al* (28) equations were used, with 49.2% of men presenting concordance with BF% by DXA, whereas women presented lower concordance (36).

The SF thickness measurement has been considered one of the most important techniques to estimate body fat in populational studies. The relation between the sum of SF and the total body fat is one of the main factors for this method to be considered valid to estimate BF%, and that can be well used in the context of public health since it is a low cost tool (14).

The use of SF thickness may not be sufficiently sensible to detect aging related changes, as they are represented by alteration of internal components (37). Those changes are important because there is centralization and internalization of fat over the years (14), and SF thickness is based on the principle that subcutaneous tissue fat represents the total fat, which can underestimate the adipose mass in these individuals (28). Barbosa *et al* (33), analyzing equations to predict body density in older women, found systematic errors on the use of equations based on SF thickness measures. In this sense, equations using anthropometric measures of body mass, height, BMI and circumferences are alternatives which have demonstrated good results on the estimation of body components in older adults (31).

Among the equations developed from BMI and circumferences, only the one of Lean *et al* (32) for the male gender and the one of Deurenberg *et al* (31) for both genders presented similarity with BF% estimated by DXA. The equation of Lean *et al* (25), which uses measures of WC and age, underestimated BF% in men and presented a concordance of

58.8% of DXA scores. The WC presented good relation with BF% (R^2 = 0.77), which could explain, in part, the validity of this equation to estimate BF% in elderly.

The equation of Deurenberg *et al* (31), which uses measures of BMI and age, presented CE of 0.69% and SEE considered as not recommended according to Lean *et al* (32) validation criteria, despite the excellent applicability, because it does not require SF measures and other variables which may difficult the field work. The concordance of the equation of Deurenberg *et al* (31) was better in female gender (58.7%), showing a trend of overestimating BF% values.

The equations which use BMI, age and gender in the estimation of body fat have been considered as an alternative for diagnosis studies on issues related to the adiposity accumulation, featuring attractions such as simplicity in data collection and the possibility of use in large populations, besides their direct relation with total body fat (31). Nevertheless, the relation of BMI with BF% is smaller in elderly than in adults (38). However, BMI, in this study, was shown as a good predictor of body fat in men (R^2 = 0.70) and in women (R^2 = 0.73), demonstrating the possible applicability of equations based on BMI measures.

For men, the graphical analysis of Bland and Altman (26) revealed the best concordance of DXA with the equation of Lean *et al* (32), to present the lowest mean difference (0.47%) and CCC = 0.85, underestimating men BF% in less than 0.5%. For women, the equation of Deurenberg *et al* (31) was the one that presented the best concordance with DXA, presenting mean difference of 0.45% and CCC = 0.81%.

The variations in nutritional status of the participants may have limited the use of body composition variables, specially the SF thickness. Factors such as the experience of the person who carried out the anthropometry, equipment used, standardization and location of the anatomic point of anthropometric measures represent notable errors in the evaluation of the body composition. Moreover, future research should also investigate visceral adipose tissue using other techniques such as computed tomography scan.

It is important to highlight that due to differences in the pattern of fat distribution among the different age groups, the estimates obtained by means of equations found in the literature may present important systematic errors, influencing the diagnosis accuracy (39). Aspects such as the selection of the most appropriate equation, equipment calibration and accuracy, standardization of techniques and evaluator's level of training, shall be carefully defined in the studies, to minimize the measure errors (29). When is not possible to evaluate body fat in older adults using DXA in clinical practice, the best equation for male is the one of Lean et al (32), which uses the waist circumference, and for women the one of Deurenberg et al (31), developed from the body mass index. Waist circumference and BMI are measures already incorporated in clinical practice. However, there is still a need for specific equations for older adults, since both equations showed considerable limitations in predicting body fat percentage.

Conclusion

Overall, all the equations produced different results from the gold standard (DXA). However, the best equation for men was the one of Lean et al which uses the WC and, for women, the one of Deurenberg et al developed from the BMI. The equations that use anthropometric measures, reflecting the total (BMI) and visceral (WC) adiposity seem to predict the BF% more accurately in older adults than the ones that also use the SF (subcutaneous fat). The need for developing specific equations for older adults still remains, because even the two equations mentioned earlier presented considerable limitations to predict body fat percentage.

Acknowledgments: The authors thank the Brazilian National Council for Scientific and Technological Development (CNPq) for the financial support and research scholarships granted and the State of Goias Research Foundation (FAPEG) for the PhD's scholarship granted. To the older adults whose participation was paramount for the accomplishment of this study.

Potential Conflict of Interests: All the authors declared that there were no potential conflicts of interest regarding this article.

References

1. Rush EC, Freitas I, Plank LD. Body size, body composition and fat distribution: comparative analysis of European, Maori, Pacific Island and Asian Indian adults. Br J Nutr. 2009;102(4):632–41.
2. Bauer UE, Briss PA, Goodman RA, Bowman BA. Prevention of chronic disease in the 21st century: Elimination of the leading preventable causes of premature death and disability in the USA. Lancet [Internet]. 2014;384(9937):45–52. Available from: http://dx.doi.org/10.1016/S0140-6736(14)60648-6
3. Patel TP, Rawal K, Bagchi AK, Akolkar G, Bernardes N, da Silva Dias D, et al. Insulin resistance: an additional risk factor in the pathogenesis of cardiovascular disease in type 2 diabetes. Heart Fail Rev. 2016;21(1):11–23.
4. Bhupathiraju SN, Hu FB. Epidemiology of obesity and diabetes and their cardiovascular complications. Circ Res. 2016;118(11):1723–35.
5. Ward LC. Human body composition: yesterday, today, and tomorrow. Eur J Clin Nutr. 2018;72(9):1201–7.
6. Lemos T, Gallagher D. Current body composition measurement techniques. Curr Opin Endocrinol Diabetes Obes. 2017;24(5):310.
7. Marra M, Sammarco R, De Lorenzo A, Iellamo F, Siervo M, Pietrobelli A, et al. Assessment of Body Composition in Health and Disease Using Bioelectrical Impedance Analysis (BIA) and Dual Energy X-Ray Absorptiometry (DXA): A Critical Overview. Contrast Media Mol Imaging. 2019;2019.
8. Hughes VA, Roubenoff R, Wood M, Frontera WR, Evans WJ, Fiatarone Singh MA. Anthropometric assessment of 10-y changes in body composition in the elderly. Am J Clin Nutr. 2004;80(2):475–82.
9. Brodie D, Vicki Moscrip MSC H, Hutcheon R. Body composition measurement: a review of hydrodensitometry, anthropometry, and impedance methods. Nutrition. 1998;14(3):296–310.
10. Rech CR, Augustemak de Lima LR, Cordeiro BA, Petroski EL, Vasconcelos F de AG de. Validity of anthropometric equations for the estimation of body fat in older adults individuals from southern Brazil. Rev Bras Cineantropometria e Desempenho Hum. 2009 Dec 11;12(1):1–7.
11. Heyward V. ASEP METHODS RECOMMENDATION: BODY COMPOSITION ASSESSMENT. J Exerc Physiol online. 2001;4(4).
12. López-Taylor JR, González-Mendoza RG, Gaytán-González A, Jiménez-

Alvarado JA, Villegas-Balcázar M, Jáuregui-Ulloa EE, et al. Accuracy of Anthropometric Equations for Estimating Body Fat in Professional Male Soccer Players Compared with DXA. J Sports Med. 2018;2018.

13. Bacchi E, Cavedon V, Zancanaro C, Moghetti P, Milanese C. Comparison between dual-energy X-ray absorptiometry and skinfold thickness in assessing body fat in overweigh/obese adult patients with type-2 diabetes. Sci Rep [Internet]. 2017 Dec 12 [cited 2018 Dec 1];7(1):17424. Available from: http://www.ncbi.nlm.nih.gov/pubmed/29234125

14. Silveira EA, Ferreira CC da C, Pagotto V, Santos AS e A de C, Velasquez-Melendez G. Total and central obesity in elderly associated with a marker of undernutrition in early life–sitting height-to-stature ratio: A nutritional paradox. Am J Hum Biol. 2017;29(3):e22977.

15. Ferreira CC da C, Peixoto M do RG, Barbosa MA, Silveira ÉA. Prevalence of Cardiovascular Risk Factors in Elderly Individuals treated in the Brazilian Public Health System in Goiânia. Arq Bras Cardiol. 2010 Oct;95(5):621–8.

16. Karthikbabu S, Solomon JM, Manikandan N, Rao BK, Chakrapani M, Nayak A. Role of Trunk Rehabilitation on Trunk Control, Balance and Gait in Patients with Chronic Stroke: A Pre-Post Design. Neurosci Med. 2011;02(02):61–7.

17. Browner WS. Estimating sample size and power. Des Clin Res an Epidemiol approach. 1988;139–50.

18. Lohman TG, Roche AF, Martorell R. Anthropometric standardization reference manual. Vol. 177. Human kinetics books Champaign, IL; 1988.

19. Habicht J-P. Estandarización de métodos epidemiológicos cuantitativos sobre el terreno. 1974;

20. Gordon CC, Chumlea WC, Roche AF. Stature, recumbent length, and weight. Anthr Stand Ref manual Champaign Hum Kinet Books. 1988;3–8.

21. Callaway CW. Circumferences. Anthr Stand Ref Man. 1988;

22. Harrison GG, Buskirk ER, Carter JL, Johnston FE, Lohman TG, Pollock ML. & Wilmore, JACK (1988). Skinfold thicknesses and measurement technique. Anthr Stand Ref Man. 1988;55–80.

23. Heyward VH, Stolarczyk LM. Applied body composition assessment. 2000.

24. Siri WE. Body composition from fluid spaces and density: analysis of methods. Tech Meas body Compos. 1961;61:223–44.

25. Lohman TG. Advances in body composition assessment. 1992. Champaign, Hum

Kinet Publ.
26. Bland JM, Altman DG. Comparing methods of measurement: why plotting difference against standard method is misleading. Lancet. 1995;346(8982):1085–7.
27. Lawrence I, Lin K. A concordance correlation coefficient to evaluate reproducibility. Biometrics. 1989;255–68.
28. Visser M, Van Den Heuvel E, Deurenberg P. Prediction equations for the estimation of body composition in the elderly using anthropometric data. Br J Nutr. 1994;71(6):823–33.
29. Durnin JVGA, Womersley J. Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years. Br J Nutr. 1974;32(1):77–97.
30. Cruz-Jentoft AJ. Sarcopenia: A clinical review. Rev Clin Gerontol. 2013;23(4):267–74.
31. Deurenberg P, Weststrate JA, Seidell JC. Body mass index as a measure of body fatness: age-and sex-specific prediction formulas. Br J Nutr. 1991;65(2):105–14.
32. Lean ME, Han TS, Deurenberg P. Predicting body composition by densitometry from simple anthropometric measurements. Am J Clin Nutr. 1996;63(1):4–14.
33. Rodrigues Barbosa A, Santarém JM, Souza Meirelles E, Nunes Marucci M de F. Comparação da gordura corporal de mulheres idosas segundo antropometria, bioimpedância e DEXA. Arch Latinoam Nutr. 2001;51(1):49–56.
34. Pagotto V, Silveira EA. Methods, Diagnostic Criteria, Cutoff Points, and Prevalence of Sarcopenia among Older People. Sci World J. 2014;2014(August 2016):1–11.
35. Pagotto V, Santos KF dos, Malaquias SG, Bachion MM, Silveira EA. Calf circumference: clinical validation for evaluation of muscle mass in the elderly. Rev Bras Enferm. 2018;71(2):322–8.
36. Rech CR, Cordeiro BA, Petroski EL, Vasconcelos F de AG de. Estimating body fat from skinfold thicknesses in the elderly. Rev Nutr. 2010 Feb;23(1):17–26.
37. Duarte MGF, Duarte PO, Pelichek A, Ferriolli E, Moriguti JC, Pfrimer K, et al. Comparison of body composition analysis methods among centenary women: Seeking simpler methods. SAGE open Med. 2019;7:2050312119865126.
38. Diniz KO, Rocha SV, Santos CA. Índice de massa corporal e indicadores antropométricos de adiposidade em idosos residentes em áreas rurais. Estud

Interdiscip sobre o Envelhec. 2015;20(2).

39. Neves T, Lopes MBM, Souza MGC, Martins NMC, Fett CA, Fett WCR. Concordância entre diferentes equações antropométricas na predição de gordura corporal em idosos. Rev Kairós Gerontol. 2016;19(2):259–77.

40. Gallagher D, Heymsfield SB, Heo M, Jebb SA, Murgatroyd PR, Sakamoto Y. Healthy percentage body fat ranges: an approach for developing guidelines based on body mass index. Am J Clin Nutr. 2000;72(3):694–701.

41. Svendsen OL, Haarbo J, Heitmann BL, Gotfredsen A, Christiansen C. Measurement of body fat in elderly subjects by dual-energy x-ray absorptiometry, bioelectrical impedance, and anthropometry. Am J Clin Nutr. 1991;53(5):1117–23.

Table 1. Anthropometric equations to estimate body fat percentage in the older adults.

Authors	Year	n	Age (years)	Country	Method	Equation
				Men		
SF Thickness						
Durnin and Womersley(29)*	1974	24	50-72	Scotland	PH	D= 1.1765 - 0.0744 $\log_{10}(X_1)$
Durnin and Womersley(29)**	1974	209	17-72	Scotland	PH	D= 1.1715 - 0.0779 $\log_{10}(X_1)$
Visser *et al.*(28)	1994	76	60-87	Holland	PH	D= 0.0186 (1Ŧ) - 0.0300 log (X_2) +1.0481
Lean *et al.*(32)	1996	63	18-65	England	PH	BF%= 0.353 (WC) + 0.756 (TR) + 0.235 (age) - 26.4
BMI						
Visser *et al.*[(26)]	1994	76	60-87	Holland	PH	D= 0.0226 (1Ŧ) – 0.0022 (BMI) + 1.0605
Deurenberg *et al.*(31)	1991	521	7-83	Holland	PH	BF%= 1.2 (BMI) + 0.23 (age) – 10.8 (1Ŧ) – 5.4
Gallagher *et al.*(40)	2000	1626	20-59	England, US and Japan	DXA	BF% = 64.5 - 848 x (1/BMI) + (0.079 x age) – (16.4 x 1Ŧ) + (0.05 x 1Ŧ x age) + (39.0 x 1Ŧ) x (1/BMI)
Circumferences						
Lean *et al.* (32)	1996	63	18-65	England	PH	BF%= 0.567 (WC) + 0.101(age)-31.8
Svendsen *et al.* (41)	1991	23	70	Denmark	DXA	BF%= 50.26 – 0.42 (HC) – 0.29 (EST) + 0.72
				Women		
SF Thickness						
Durnin and Womersley(29)*	1974	37	50-68	Scotland	PH	D= 1.1339 - 0.0645 $\log_{10}(X_1)$
Durnin and Womersley(29)**	1974	272	17-68	Scotland	PH	D= 1.1567 - 0.0717 $\log_{10}(X_1)$
Visser *et al* .(28)	1994	128	60-87	Holland	PH	D= 0.0186 (0Ŧ) - 0.0300 log (X_2) + 1.0481
Lean *et al.* (32)	1996	84	18-65	England	PH	BF%= 0.232 (WC) + 0.657 (TR) + 0.215 (age) - 5.5
Svendsen *et al.*(41)	1991	23	70	Denmark	DXA	BF%= 1.40 (BMI) + 0.48 (TR) – 25.81
BMI						
Visser *et al.*[(26)]	1994	128	60-87	Holland	PH	D= 0.0226 (0Ŧ) – 0.0022 (BMI) + 1.0605
Deurenberg *et al.* (31)	1991	708	7-83	Holland	PH	BF%= 1.2 (BMI) + 0.23 (ID) – 10.8 (0Ŧ) – 5.4
Gallagher *et al.* (40)	2000	1626	20-59	England, US and Japan	DXA	BF% = 64.5 - 848 x (1/BMI) + (0.079 x age) – (16.4 x 0Ŧ) + (0.05 x 0Ŧ x age) + (39.0 x 0Ŧ) x (1/BMI)

*Equation specific for the elderly. ** Equation generalized for a broad group age. Method: technique used in the development and validation of regression equations. PH: hydrostatic weighing. DXA: dual energy X-ray absorptiometry. D: body density. BF%: percentage of body fat. Age (years). BM: Body mass (kg). EST: height (cm). BMI: Body Mass Index (kg/m^2); BI: bicipital skinfold; TR: tricipital skinfold; SE: subscapular skinfold; SI: supra-iliac skinfold; WC: waist circumference; HC: hip circumference. X_1: Σ (tricipital, subescapular, bicipital, supra-iliac); X_2: Σ (bicipital, tricipital). Ŧ represents the constant for the gender (female=0 and male=1).

Table 2. Mean, standard deviation, minimum and maximum (amplitude) of anthropometric variables and fat percentage in older adults, by sex.

	Men (n=52)			**Women (n=75)**		
	Mean±SD	Median	Amplitude	Mean±SD	Median	Amplitude
BMI (kg/m²)*	25.75±4.05	26.10	14.42/35.36	27.75±5.58	26.88	17.16/40.02
WC (cm)	95.69±11.48	98.05	61.00/114.50	93.49±14.67	94.20	66.25/160.40
SF SE (mm)**	19.99±7.94	19.41	5.70/ 39.67	26.07±10.84	25.00	8.00/77.50
SF TR (mm)**	13.51±6.04	12.67	3.50/31.17	27.03±9.71	24.00	6.83/ 52.00
SF BI (mm)**	6.55±3.58	6.00	2.00/18.17	13.92±6.56	13.00	2.83/36.67
SF SI (mm)**	19.49±7.46	20.33	3.50/35.00	23.81±6.30	24.33	9.00/39.00
BF% DXA**	30.21±8.63	31.00	5.40/47.40	43.44±7.92	43.80	21.80/57.10

t-test for independent samples: * p <0,05; ** p <0,001; BMI: Body Mass Index; WC: waist circumference; SF: skinfold thickness; SE: subscapular; TR: tricipital; BI: bicipital; SI: supra-iliac; BF% DXA: body fat percentage by dual energy X-ray absorptiometry; SD: standard-deviation

Table 3. Analysis of validation criteria of anthropometric equations to estimate body fat rate in older adults by sex.

Methods	Mean±SD	CE	r	TE	SEE	%C
	Men (n=52)					
BF% DXA	30.21±8.63					
SF Thickness						
Durnin and Womersley (Esp)[25]	22.81±6.32*	-7.04	0.91	8.3	3.58	15.4
Durnin and Womersley (Gen)[25]	27.88±6.75*	-2.33	0.91	4.4	3.58	53.8
Visser *et al.*(28)	31.07±2.86	0.85	0.90	6.2	3.82	51.2
Lean *et al.* (32)	34.12±8.13*	4.08	0.92	7.5	3.37	43.1
BMI						
Visser *et al.*(28)	32.28±4.17*	2.06	0.84	7.48	4.77	46.1
Deurenberg *et al.* (31)	30.91±5.04	0.69	0.84	6.66	4.71	51.9
Gallagher *et al.* (40)	24.91± 5.87*	-5.30	0.87	6.97	4.31	30.8
Circumferences						
Lean *et al.* (32)	29.58±6.58	-0.47	0.88	4.14	4.06	58.8
Svendsen *et al.* (41)	59.89±6.61*	29.67	0.70	31.41	6.19	0.0
	Women (n=75)					
BF% DXA	43.44±7.92					
SF Thickness						
Durnin and Womersley (Esp) (29)	40.59±4.56*	-2.84	0.87	5.3	3.87	48.0
Durnin and Womersley (Gen) (29)	36.33±4.98*	-7.11	0.87	8.3	3.87	21.3
Visser *et al.*(28)	44.67±2.53	1.24	0.81	6.2	4.71	42.7
Lean *et al.* (32)	48.90±8.95*	5.46	0.81	7.5	4.62	33.3
Svendsen *et al.*[30]	26.01±11.75*	-17.42	0.87	18.73	3.90	1.3
BMI						
Visser *et al.*[26]	45.34±6.12*	1.91	0.85	4.47	4.15	56.0
Deurenberg *et al.* (31)	43.88±6.78	0.45	0.83	4.42	4.46	58.7
Gallagher *et al.* (40)	32.90±6.38*	-10.53	0.89	11.16	3.67	2.7

Esp: equation specific for elderly; Gen: equation generalized for a broad age group; * differs significantly (p<0.05) paired t-test; SD: standard deviation CE: constant error; r: Pearson linear correlation coefficient; TE: total error; SEE: standard error of the estimate; %C: agreement percentage with validation limit %BF(±3,5%); BF% DXA: body fat percentage by dual energy X-ray absorptiometry;

Table 4. Precision, accuracy, concordance correlation coefficient (CCC) and mean differences of the anthropometrical equations to estimate body fat percentage in older adults by sex.

Methods	Precision	Accuracy	CCC	Mean difference (95% limit of agreement)
		Men (n=52)		
SF Thickness				
Durnin and Womersley (Esp) (29)	0.912	0.640	0.584	-7.405 (-14.987; 0.178)
Durnin and Womersley (Gen) (29)	0.912	0.928	0.846	-2.334 (-9.617; 4.949)
Visser *et al.*(28)	0.899	0.592	0.532	0.859 (-11.269; 12.987)
Lean *et al.* (32)	0.922	0.891	0.822	4.080 (-2.469; 10.629)
BMI				
Visser *et al.*(28)	0.837	0.748	0.626	2.063 (-8.963; 13.090)
Deurenberg *et al.*(28)	0.841	0.867	0.729	0.698 (-9.432; 10.827)
Gallagher *et al.* (40)	0.870	0.736	0.640	-5.305 (-14.258; 3.648)
Circumferences				
Lean *et al.* (32)	0.885	0.962	0.852	-0.467 (-8.610; 7.675)
Svendsen *et al.* (41)	0.704	0.112	0.079	29.679 (17.614; 41.744)
		Women (n=75)		
SF Thickness				
Durnin and Womersley (Esp) (29)	0.875	0.787	0.689	-2.842 (-11.688; - 6.004)
Durnin and Womersley (Gen) (29)	0.875	0.569	0.497	-7.106 (-15.552; 1.340)
Visser *et al.*(28)	0.807	0.567	0.458	1.236 (-10.658; 13.131)
Lean *et al.* (32)	0.815	0.819	0.668	5.461 (-4.777; 15.699)
Svendsen *et al.* (41)	0.872	0.366	0.319	-17.425 (-29.587; -5.263)
BMI				
Visser *et al.*(28)	0.854	0.933	0.797	1.907 (-6.281; 10.096)
Deurenberg *et al.* (31)	0.829	0.986	0.818	0.450 (-8.236; 9.135)
Gallagher *et al.* (40)	0.888	0.468	0.416	-10.533 (-17.789; -3.278)

Esp: equation specific for elderly; Gen: equation generalized for a broad age group; CCC: concordance correlation coefficient.