2024, Retos, 59, 401-410

What is the best predictor of body fat percentage for older brazilian women?
¿Cuál es el mejor predictor del porcentaje de grasa corporal en las mujeres brasileñas ancianas?

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Abstract. This study aimed to investigate the validity of several equations and predictive indices for estimating body fat percentage (%BF) in 152 older women, with an average age of 67.4 years and an average body mass index (BMI) of 28.65 kg/m². To this end, anthropometric measurements including height, body weight, circumferences (waist and hip), and a dual energy X-ray absorptiometry (DXA) scan were performed. All measurements were performed by trained researchers following specific protocols. The results were compared to the dual energy X-ray absorptiometry (DXA) technique, which is considered the reference method. The analyzed equations showed moderate to good correlation coefficients with DXA, with particular emphasis on Visser's equation 6, which showed the best correlation ($r = 0.752$, $p < 0.001$). However, the agreement between the equations and DXA, as assessed by the Lin concordance coefficient, was classified as poor ($\rho c < 0.90$). This indicates that although the equations have a positive correlation with body composition, they tend to deviate from the identity line when compared to the reference method. Additionally, the equations showed high sensitivity for detecting obesity when the cut-off point of 30% body fat was adopted, indicating a good ability to identify the presence of the condition. However, the equations, with the exception of equation 4, showed low specificity, meaning they had limited ability to detect normal individuals, resulting in a low negative predictive value. The results suggest that BF% equations and indices are dependent on the populations in which they were developed. The specificity and sensitivity of these equations may vary, and it is important to carefully select the most appropriate equation for estimating BF% in older Brazilian women.

Keywords: Anthropometry; body composition; older adults.

Resumen. Este estudio tuvo como objetivo investigar la validez de varias ecuaciones e índices predictivos para estimar el porcentaje de grasa corporal (%GC) en 152 mujeres mayores, con una edad promedio de 67,4 años y un índice de masa corporal (IMC) promedio de 28,65 kg/m². Para ello, se realizaron mediciones antropométricas que incluyeron altura, peso corporal, circunferencias (cintura y cadera) y una absorciometría dual de rayos X (DXA). Todas las mediciones fueron realizadas por investigadores capacitados siguiendo protocolos específicos. Los resultados se compararon con la técnica de absorciometría dual de rayos X (DXA), que se considera el método de referencia. Las ecuaciones analizadas mostraron coeficientes de correlación de moderados a buenos con DXA, con especial énfasis en la ecuación 6 de Visser, que mostró la mejor correlación ($r = 0{,}752$, $p < 0{,}001$). Sin embargo, la concordancia entre las ecuaciones y la DXA, evaluada mediante el coeficiente de concordancia de Lin, se clasificó como pobre ($\rho c < 0{,}90$). Esto indica que, aunque las ecuaciones tienen una correlación positiva con la composición corporal, tienden a desviarse de la línea de identidad cuando se comparan con el método de referencia. Además, las ecuaciones mostraron una alta sensibilidad para detectar la obesidad cuando se adoptó el punto de corte del 30% de grasa corporal, lo que indica una buena capacidad para identificar la presencia de la afección. Sin embargo, las ecuaciones, con la excepción de la ecuación 4, mostraron una especificidad baja, lo que significa que tenían una capacidad limitada para detectar individuos normales, lo que resultó en un valor predictivo negativo bajo. Los resultados sugieren que las ecuaciones e índices de %BF dependen de las poblaciones en las que se desarrollaron. La especificidad y sensibilidad de estas ecuaciones pueden variar, y es importante seleccionar cuidadosamente la ecuación más adecuada para estimar el % de GC en mujeres brasileñas mayores.

Palabras clave: Antropometría; composición corporal; adultos mayores.

Fecha recepción: 17-01-24. Fecha de aceptación: 19-07-24

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Introduction

The prevalence of obesity in the world has grown alarmingly in all age groups, increasing from 10% to 40% in the last 10 years (AGHA; AGHA, 2017). Obesity has increased by 72% in the last 13 years in Brazil, from 11.8% in 2006 to 20.3% in 2019 (METABÓLICA, 2022). At the same time, the aging process can be related to obesity, as advancing age favors a decrease in physical activities and, consequently, several changes in body composition, such as a reduction in fat-free mass, especially muscle mass and of bone mineral density. (LIN; YU; YANG; WU et al., 2022; SANTOS; SANTOS JÚNIOR; ROCHA; REIS et al., 2014). It has been estimated that there is a loss of about 5% of muscle mass every decade from the age of 40, with a faster decline after the age of 65 (KELLER; ENGELHARDT, 2013). This muscle mass and strength loss with age is known as sarcopenia, becoming recognized as one of the main causes of disability and morbidity in the older adult population (WESTBURY; BEAUDART; BRUYÈRE; CAULEY et al., 2023).

Measuring and monitoring changes in body composition during aging is important for maintaining health and well-being. There are a variety of methods that can be used for this purpose, including indirect methods such as computed tomography, magnetic resonance imaging, and dual-energy X-ray absorptiometry (DXA), and the double indirect methods such as skinfold thickness and body perimeters (HEYWARD; WAGNER, 2004). Indirect methods are more accurate and reliable, but they are expensive, require specialized sites and technicians, and they are not available for large-scale use in developing countries (HEYWARD;

WAGNER, 2004). On the other hand, double indirect methods are less accurate but cheaper and more applicable to population research. Furthermore, the double indirect methods predict body fat from prediction equations (BERGMAN; STEFANOVSKI; BUCHANAN; SUMNER et al., 2011; DEURENBERG; YAP; VAN STAVEREN, 1998; GALLAGHER; VISSER; SEPÚLVEDA; PIERSON et al., 1996; GÓMEZ-AMBROSI; SILVA; CATALÁN; RODRÍGUEZ et al., 2012; KAGAWA; BYRNE; HILLS, 2008; VISSER; VAN DEN HEUVEL; DEURENBERG, 1994; WOOLCOTT; BERGMAN, 2018). These equations can be classified as general or specific, being respectively developed from a more heterogeneous or homogeneous population in terms of age, sex, ethnicity, etc. (HEYWARD; WAGNER, 2004). In theoretical and empirical terms, it seems that specific equations are more precise in predicting body fat when compared to general equations when used for the group in which they were developed (for example – an older adult-specific equation to predict body fat).

All body fat prediction equations, whether general or specific, generally use variables individually or in combination to estimate body fat and/or body density (HEYWARD, 1998; HEYWARD; WAGNER, 2004). These independent variables may include age, body weight, height, circumferences, and/or skinfolds. It is believed that measurement of body weight, height, and circumferences does not require advanced training, unlike skinfold measurements (HEYWARD, 1998; HEYWARD; WAGNER, 2004). Thus, in addition to the error associated with the regression technique (number of individuals per independent variables; and the population chosen for the development of the equations), a likely related problem would be skinfold measurements which require standardization, training, and evaluator experience to minimize measurement errors (inter-rater and intra-rater reproducibility) (DUREN; SHERWOOD; CZERWINSKI; LEE et al., 2008; HEYWARD, 1998; HEYWARD; WAGNER, 2004; RIPKA; CINTRA-ANDRADE; ULBRICHT, 2022). Furthermore, marking the reference points and subsequently measuring the skinfold measurements is a time-consuming process, which makes its use in large population groups unfeasible (SILVA; RIBEIRO; PAVÃO; RONQUE et al., 2013). Another problem in measuring skinfolds is related to a possible limitation of adipometers for measuring skinfolds greater than 45 mm (DUREN; SHERWOOD; CZERWINSKI; LEE et al., 2008; SILVA; RIBEIRO; PAVÃO; RONQUE et al., 2013). Thus, several studies have developed fat prediction equations based on anthropometric variables to minimize the problems associated with obtaining skinfolds (BERGMAN; STEFANOVSKI; BUCHANAN; SUMNER et al., 2011; DEURENBERG; WESTSTRATE; SEIDELL, 1991; GALLAGHER; VISSER; SEPÚLVEDA; PIERSON et al., 1996; GÓMEZ-AMBROSI; SILVA; CATALÁN; RODRÍGUEZ et al., 2012; KAGAWA; BYRNE; HILLS, 2008; VISSER; VAN DEN HEUVEL; DEURENBERG, 1994; WOOLCOTT; BERGMAN, 2018) (Table 1).

Table 1.
State of art

Author	Gender	N	Age group	BMI (kg/m^2)	Body fat (%)	Ethinic*	Gold standard	r
Bergman et al. (2011)	M/F	1.956	18-67	18.5–54.7	7.5 – 61.2	Mexican and African-American	DXA	0.763
Woolcott e Bergman (2018)	M/F	12.580	20 - >60	<18.5 - >30	NR	Various*	DXA	0.807
CUN-BAE (2012)	M/F	6.510	18 – 80	NR	NR	Spanish	Bod-pod	0.900
Gallagher et al. (1996)	M/F	706	20 – 94	18 – 35.0	NR	Black and white	Hydro	0.810
Deurenberg, Yap, Van Staveren (1998)*	M/F	11.924	18 – 77	19.3 – 36.0	11.4-43.9	Various*	Various	0.938
Visser et al. (1994)	M/F	204	60 – 87	NR	NR	Netherlands	Hydro	0.818
Kagawa, Byrne, Hills (2008)	M/F	216	20 – 64	17.7 – 39.9	7.5 – 55.0	Australian	DXA	0.867

Legend: Equation three, gender (**Ŧ**), 0 to men and 1 to women; Equations four to seven, gender(**Ŧ**), 0 to women and 1 to men; age in years; Equation two and seven, height and hip circumference in meters. BD = body density. NR – No Reported

However, all the equations are generalized in relation to age group and originate from other ethnic groups, which could possibly cause inaccuracies in predicting fat in older Brazilian women. Furthermore, it would be important for these equations to have sensitivity and predictive power in identifying obesity. In view of this context, some questions arise: which equations are more sensitive and have a high positive predictive power for predicting body fat in older Brazilian adults? Consequently, this study aims to assess the validity of equations and general indices in predicting body fat percentage (BF%) derived from anthropometric variables in older women.

Material and methods

Participants

This is an observational and cross-sectional study in which the participants consisted of 152 older Brazilian women with an average age of 67.4 years (60 to 81 years) and an average BMI of 28.65 $kg.m^2$ (15 to 46 $kg.m^2$) who were intentionally selected. All participants were in an Extension Project promoted by the Physical Education Department, Federal University of Pernambuco, Campus Recife, entitled "Healthy Aging". All the participants were informed about the project and the study and signed the informed consent form (ICF). The study was approved by the Human Research Ethics Committee of the Health Sciences Center (UFPE) under protocol number 2,159,115.

Procedures

All of the volunteers completed anthropometric measurements including standing height, body mass, circumference (waist and hip), and DXA scan during a single testing session. They were all measured in light-weight clothing without metal and without shoes. All assessments were carried out between 7 and 9 am, over a period of 30 days

Anthropometric measurements

All measurements were conducted in the morning by trained researchers after the participants had fasted for a minimum of 12 h. Standing height was determined using a wall-fixed stadiometer (Standard Sanny Model ES2030; Sanny, São Paulo, Brazil) with the subject's hands positioned on their hips during a maximal inhalation. Body mass was determined using a calibrated electronic scale (Well Model W200/100A; Welmy, Santa Barbara d´Oeste, Brazil). Body mass index (BMI) was calculated by dividing the weight (kg) by the height squared (m^2) (Quetelet's equation).

Waist and hip circumference (cm) were measured with a steel measuring tape (Cescorf, Porto Alegre, Brazil). Waist circumference was taken as the smallest measure between the lowest rib and iliac crest and hip circumference was measured at the level of the widest circumference over the great trochanters, with the volunteer positioned with their legs adducted. All measurements were taken in triplicate and performed by the same-trained examiner (>15 years of experience in anthropometric measures, >1000 anthropometric assessments/year).

Equations to predict body fat

The following equations were used to predict the body fat percentage (BF%): the Body Adiposity Index (BAI) elaborated by Bergman et al. (BERGMAN; STEFANOVSKI; BUCHANAN; SUMNER et al., 2011) (Equation one); the equation proposed by Woolcott; Bergman (2018) (Equation two); the "CUN-BAE" adiposity estimator equation by the Clínica Universidad de Navarra-body (GÓMEZ-AMBROSI; SILVA; CATALÁN; RODRÍGUEZ et al., 2012) (Equation three); the equation by Gallagher et al. (1996) (Equation four); the equation by Deurenberg, Yap, Van Staveren (1998) (Equation five); the equation by Visser et al. (1994) (Equation six); and the equation by Kagawa, Byrne, Hills (2008) (Equation seven). The Siri Equation was used to convert body density into fat percentage (SIRI, 1961). The equations are available in Table 2.

Table 2.
Anthropometric equations for estimating the percentage of body fat (%BF) and body density in the elderly.

Equation	Author	Equation
One (1)	Bergman et al. (2011)	%BF = [hip circumference (cm)/ (height x root square height (m)] – 18
Two (2)	Woolcott e Bergman (2018)	%BF = 76 - [20*(height/ (hip circumference (cm)/100)]
Three (3)	CUN-BAE (2012)	%BF = −44.988 + (0.503 × age) + (10.689 × Ŧ) + (3.172 × BMI) − (0.026 × BMI^2) + (0.181 × BMI × Ŧ) − (0.02 × IMC × age) − (0.005 × BMI^2 × Ŧ) + (0.0002 × IMC^2 × age).
Four (4)	Gallagher et al.(1996)	%BF = 64.5 −(848 × (1/BMI)) + (0.079 × age) − (16.4 × Ŧ) + (0.05 × Ŧ × age) + (39.0 × Ŧ × (1/BMI)).
Five (5)	Deurenberg, Yap, Van Staveren (1998)	%BF = − (11.4 × Ŧ) + (0.20 × age) + (1.294 × BMI) − 8.
Six (6)	Visser et al. (1994)	BD = 0.0226 x (Ŧ) – 0.0022(BMI) + 1,0605
Seven (7)	Kagawa, Byrne, Hills (2008)	%BF= − 8.339 + (92.701 × waist/ height) − (0.078 × age) − (11.062 × Ŧ).

Legend: Equation three, gender (Ŧ), 0 to men and 1 to women; Equations four to seven, gender (Ŧ), 0 to women and 1 to men; age in years; Equation two and seven, heigh and hip circumference in meters. BD = body density.

Dual-energy X-ray absorptiometry

The DXA of the entire body was measured by the Prodigy Primo instrument (GE, Brazil) and input into the GE Healthcare enCORE version 10.0 software program to measure the body fat percentage (BF%). All volunteers remained motionless in dorsal decubitus within the DXA measurement area throughout the procedure, which lasted an average of 15 minutes.

Statistical analysis

Descriptive statistical procedures were performed (central tendency and dispersion measures) for the variables characterizing the volunteers and predictive equations. Validity was determined using Pearson's correlation and Lin's concordance correlation coefficient was used to assess the concordance between the equations and DXA. Lin's concordance correlation coefficient is a measure of the agreement between two methods or persons and it combines precision and accuracy measures to determine how far the observed data deviate from perfect agreement (LIN, 1989; NITA; ELLIS; MADDEN, 2003). The correlation coefficient > 0.90 was classified as excellent, 0.75-0.90 as good, 0.60-0.75 as moderate, and < 0.60 as poor (FOKKEMA; KOOIMAN; KRIJNEN; CP et al., 2017). MCBRIDE (2005) suggests the following descriptive scale for Lin's concordance correlation coefficient values: < 0.90 Poor, 0.90-0.95 Moderate, 0.95-0.99 Substantial, >0.99 Almost perfect. Furthermore, we used a Bland–Altman plot to illustrate the concordance of the equations with the DXA.

The average total error percentage was calculated by the difference between DexaBF% and BF%Equations divided by DexaBF% and multiplied by 100. We used the proposal by NELSON; KAMINSKY; DICKIN and MONTOYE (2016), which establishes a 10% threshold to classify the validity. The average error was calculated by the difference between the BF%Equations, respective of each equation and DexaBF%. Mean absolute error (MAE) was calculated as the mean of the absolute distances between the predictive equations and DXA. Mean absolute percentage error (MAPE) relative was measured from the number of occurrences in which the difference between the DexaBF% and the BF%Equations was less than ± 5% fat (DELGADO-GONZALO; PARAK; TARNICERIU; RENEVEY et al., 2015). We adopted 30% body fat as the limit between the normal classification and obesity to calculate the agreement. Positive (PPV) and negative (NPV) predictive values, sensitivity and specificity were calculated for each equation using the numbers of volunteers with true positive (TP), true negative (TN), false positive (FP) and false negative (FN) results. The data were analyzed with the Statistica for Windows (v. 12) program, and the graphs were constructed with the GraphPad Prism 8.0 for Windows program. Statistical significance at $p < 0.05$ was adopted for all analyzes.

Results

Table 3 showed the anthropometric characteristics of the volunteers.

Table 3.
Anthropometric characteristics of the volunteers (n=152).

	Average	Standard deviation	Min	Max	C.V. (%)
Age (years)	67.45	4.79	60.00	81.20	7.10
Body mass (kg)	66.51	13.52	34.30	112.10	20.33
Height (m)	1.53	0.06	1.36	1.68	3.83
BMI (kg/m^2)	28.52	5.24	15.24	46.06	18.36
Waist (cm)	93.98	12.72	62.00	132.00	12.72
Hip (cm)	101.74	10.27	80.00	133.00	10.10
Waist/Hip	0.92	0.07	0.61	1.14	7.65
DXA (%BF)	42.81	5.73	22.00	56.40	13.39

Legend: Min.= Minimun; Max.= Maximun; C.V. = Coefficient of Variation; BMI= Body mass index (kg/m2); DXA = %BF.

Table 4 showed the mean values and dispersion of the percentage of fat obtained from the DXA and the predictive equations.

Table 4.
Comparison of mean body fat percentage values between DXA and predictive equations.

	Average	Standard deviation	Min	Max	C.V. (%)	Paired t test	p
DXA (%BF)	42.84	5.81	22.00	56.40	13.56%	Reference	
Equation 1	36.17*	5.56	21.65	53.82	15.36%	16.68	0.001
Equation 2	43.12	4.28	27.61	53.73	9.91%	0.78	0.436
Equation 3	42.23	4.98	28.22	54.74	11.79%	1.92	0.057
Equation 4	39.21*	5.62	14.87	50.83	14.34%	10.78	0.001
Equation 5	41.88*	6.16	27.79	61.08	14.72%	2.68	0.008
Equation 6	44.09*	5.80	29.90	63.67	13.15%	3.72	0.003
Equation 7	43.70	7.16	24.04	70.05	16.37%	1.93	0.859

Legend: Mín = Mínimum; Max = Maximum; C.V = Coefficient of Variation; * = significant difference

Figure 1 shows the coefficients of determination (r2) and Pearson's correlation (r) and the significance level between the body fat percentage obtained by DXA and the predictive equations. All equations showed moderate correlation.

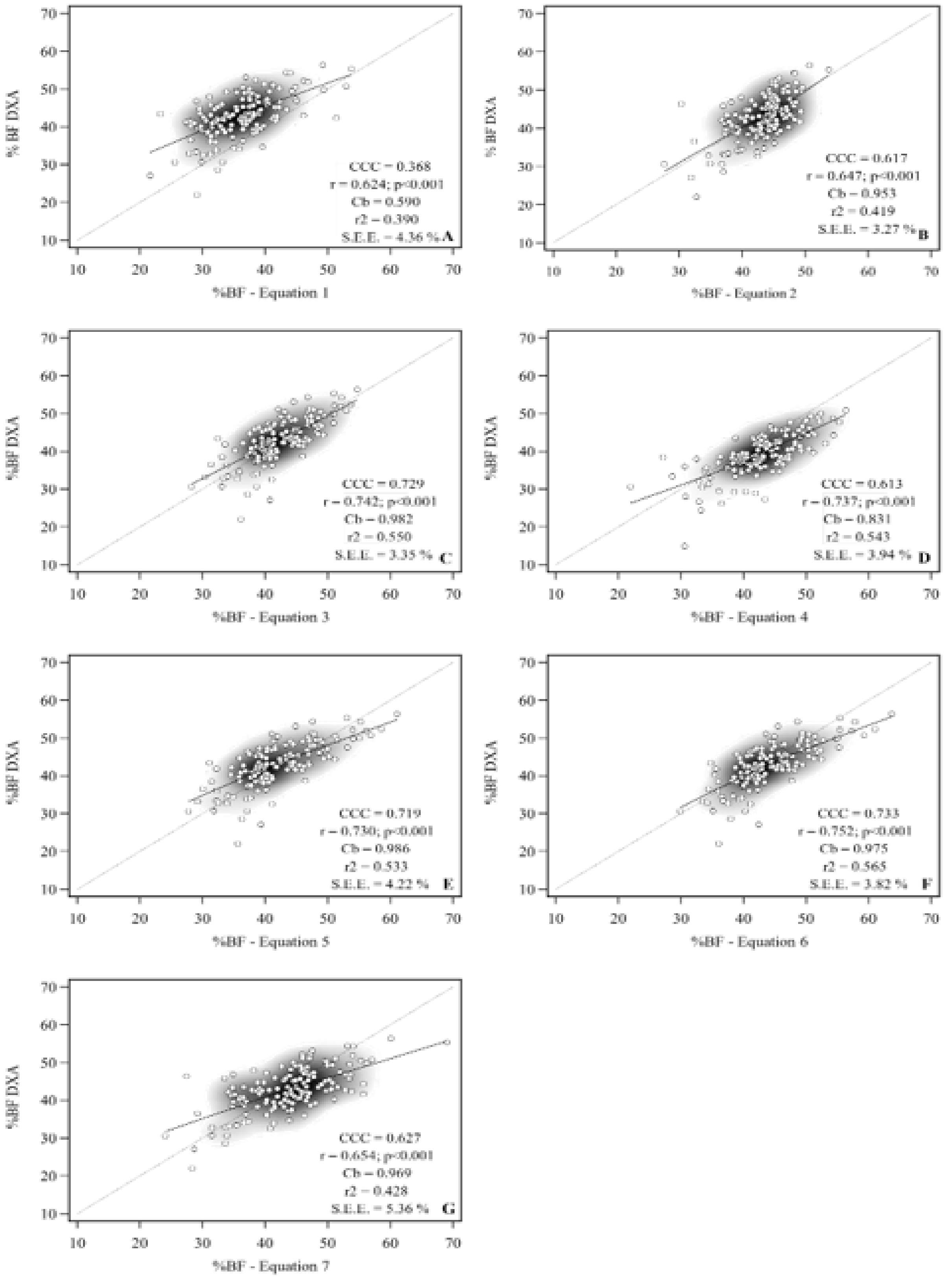

Figure 1. Correlations between DXA and predictive equations

Figure 2 shows the difference between the DXA and BF% estimated by the equations, with their respective limits of agreement. The lowest bias values and limits of agreement were found in equations 2, 3 and 4 (Table 4). Equation 1 had a -6.8% bias (LoA -16.34 to 2.99).

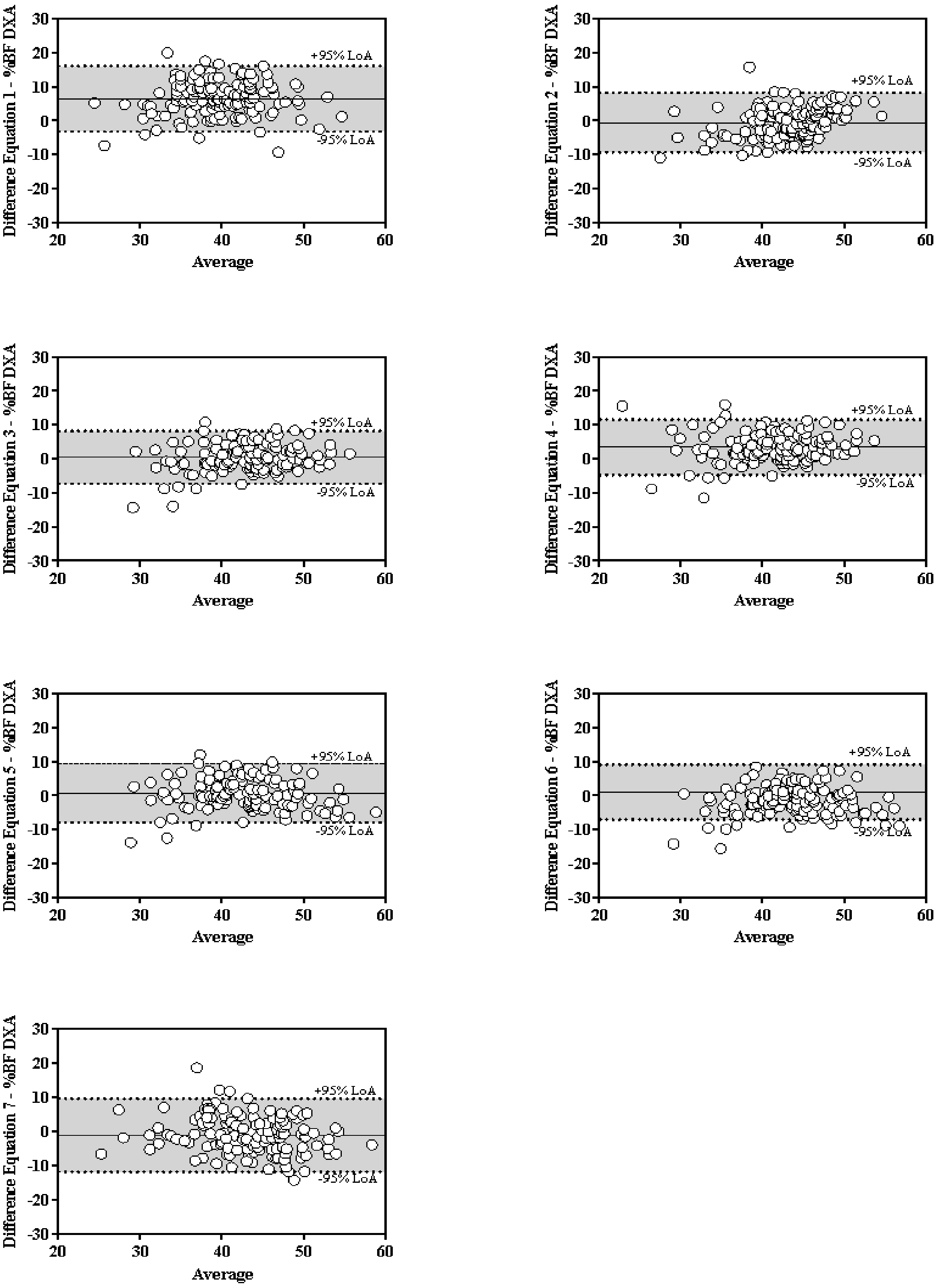

Figure 2. Bland Altman between DXA and %BF estimated by the predictive equations.

Table 5 shows the bias values obtained from the difference between DXA and BF% estimated by predictive equations (Limits of agreement (LoA), absolute and relative error and the agreement of the Normal/Obesity classification between the DXA and the prediction equations).

Table 5.
Average of the Bias, MAE, MAPE and Agreement values of the predictive equations

	Bland Altman			MAE		MAPE		
	Bias	SD	LoA	Average	SD	Average	SD	Agreement
Equation 1	6.68	4.93	-2.99 to 16.34	7.14	4.22	16.41	9.14	65.1%
Equation 2	-0.28	4.46	-8.46 to 9.02	3.70	2.48	9.05	7.03	91.4%
Equation 3	0.61	3.95	-7.13 to 8.35	3.02	2.60	7.45	8.09	90.1%
Equation 4	3.62	4.15	-4.50 to 11.76	4.42	3.29	10.52	8.54	88.2%
Equation 5	0.96	4.41	-7.69 to 9.60	3.52	2.82	8.46	8.07	90.8%
Equation 6	-1.25	4.14	-9.36 to 6.87	4.56	4.29	8.20	8.58	90.9%
Equation 7	-0.86	5.49	-11.63 to 9.89	4.47	3.30	10.63	7.86	89.5%

Legend: LoA = Limit of agreement; BIAS= Systematic error; MAE = Mean absolute error; MAPE= Mean absolute percentage error.

Table 6 shows the sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV). Equations 2, 3, 4, 5 and 6 showed high sensitivity values, meaning they have an excellent ability to detect obesity when it is present. On the other hand, the same equations, except for equation 4, showed low specificity values, which indicates that they have a low capacity to detect normal individuals (low negative predictive value).

Table 6.
Sensitivity, specificity, and predictive values of equations.

	Sensibility	Specificity	PPV	NPV
Equation 1	0.63	0.81	0.97	0.20
Equation 2	0.99	0.31	0.92	0.71
Equation 3	0.96	0.38	0.93	0.55
Equation 4	0.90	0.75	0.97	0.46
Equation 5	0.95	0.56	0.95	0.56
Equation 6	0.99	0.25	0.92	0.67
Equation 7	0.63	0.93	0.50	0.96

Legend: CI = Confidence Interval; PPV: Positive predictive value; NPV: Negative predictive value

Discussion

This study's central research objective was to evaluate the validity of equations and general indices in predicting body fat percentage %BF derived from anthropometric variables in elderly women. Comparing the data obtained by the equations and predictive indices to estimate the percentage of body fat (%BF) with the dual-energy X-ray absorptiometry (DXA) technique, considered a reference method**.**

Increased weight in adipose tissue can promote serious clinical complications in the elderly, impacting quality of life, with a consequent increase in premature morbidity related to diseases such as systemic arterial hypertension, diabetes mellitus, obstructive cardiovascular diseases and diseases of the locomotor system (COLLELUORI & VILLAREAL, 2021). It is known that obesity (excess body fat) not only affects physical, visual, and aesthetic aspects, but also leads to a metabolic imbalance and is a factor in the development of several chronic pathologies (AMARYA; SINGH; SABHARWAL, 2014; PEÑA; MARTIN-ALEMAN; ALBERTO-CARDOZO; CASTILLO-DAZA et al., 2022; PLETICOSIC-RAMÍREZ; MECÍAS CALVO; NAVARRO-PATÓN, 2024) Anthropometry has been widely used in epidemiological studies among the techniques for evaluating excess fat, mainly due to its low cost and easy application (SCAFOGLIERI; CLARYS; CATTRYSSE; BAUTMANS, 2014; SCAFOGLIERI; VAN DEN BROECK; CATTRYSSE; BAUTMANS et al., 2022).

Recent studies show the relevance of anthropometry throughout life to reflect health status. LEKNESSUND; MORELLI; STRAND; HANSEN et al. (2022) state that periodic anthropometric assessment may indirectly reflect on the quality of life of the older adult population since quantifying peripheral muscle mass is an indicator of mortality in healthy individuals. Other authors corroborate that anthropometric assessment, information, and control of body composition are essential to verify the nutritional status and prevent the risk of developing certain diseases (DA CRUZ; ALMEIDA; SCHWANKE; MORIGUCHI, 2004; DE ONIS; HABICHT, 1996; MARCHI-ALVES; YAGUI; RODRIGUES; MAZZO et al., 2011; MASTROENI; MASTROENI; ERZINGER; MARUCCI, 2010). However, it is critical to point out that the accuracy of estimating body fat percentage directly depends on the chosen method. Methods which have lower financial costs and applicability to large population groups are less accurate, which is why it is critical to determine the most accurate equation to predict body fat in older adults.

From this perspective, our study aimed to verify the validity of several equations and predictive indices of body fat percentage (BF%) in older women and to determine which one most accurately applies to older adult and Brazilian populations. Thus, 152 older women with an average age of 67.4 years and an average BMI of 28.65 kg/m^2 participated in this study. As these are national studies, our BMI results are corroborated by: ARROYO; LERA; SÁNCHEZ; BUNOUT et al. (2007) and MOREIRA; NICASTRO; CORDEIRO; COIMBRA et al. (2009), in which the average BMI value for women of similar age group was 28.5 ± 4.7 kg/m^2 and 27.3 ± 4.9 kg/m^2, respectively. When we compare the means of the BF% equation versus the DXABF%, we find that equations 2, 3 and 7 do not present statistically significant differences (Table 4); similar results were found in DEURENBERG; WESTSTRATE and SEIDELL (1991) and LEAN; HAN and DEURENBERG (1996). Unlike our study, RECH; LIMA; CORDEIRO; PETROSKI et al. (2010) found a difference between the average of the BF% equation and the DXABF% for the Visser equation (Equation 6). We recognize that some authors do not recommend the paired t-test to verify the validity of instruments, however we believe that the information may be relevant for decision-making when analyzed with other parameters.

The equations showed moderate correlation coefficients, except for equation six, which showed a good correlation coefficient ($r= 0.752$, $p<0.001$). A national study RECH; LIMA; CORDEIRO; PETROSKI et al. (2010) compared several equations with DXA and one of the equations used by the authors was equation 6, presenting similar correlation results ($r= 0.760$, $p<0.001$). Although correlation is not a unanimous tool to test the validity of an instrument, it is possible to observe that the equations have a positive and explanatory relationship with body composition. A moderate (Equations 1-5;7) to a good correlation (Equation 6) represent a reasonable explanation of the phenomenon, meaning that as we evaluate individuals with different body compositions, the BF% measured by DXA and by the equations follow the same direction.

Another alternative would be to use Lin's correlation coefficient. This analysis calculates a coefficient (ρc) from the fit of the data on the identity line (45°). All equations presented Lin's concordance correlation coefficient classified as poor $\rho c < 0.90$, which demonstrates that despite moderate to good Pearson's correlations, the relationship between the BF% of the equations increases as the DXABF% increases, however with the ordinates and abscissas mostly away from the identity line (Figure 2).

When we analyzed the Bland-Altman and compared the equations for the bias values, equations 2, 3 and 5 and 7 showed the lowest bias values (< 1.0%), with two equations underestimating (Equation 2 and 5) and two others overestimating the bias (Equations 3 and 7). In the study by RECH; LIMA; CORDEIRO; PETROSKI et al. (2010), equation 6 showed a bias of 7.6% in older women in the south of the country, while it showed the lowest bias in our study (0.61 ± 3.95). All equations showed high LoA values; the lowest value was ± 7.5% and the highest ± 10.5%, which demonstrates a large variation in the error.

All the results reinforce that the equations derived from the linear regression techniques are dependent on the populations from which they originated, meaning that it is more feasible that the equations have better accuracy in populations similar to the original populations. In our study, only equation 6 (age group 60-87 years) is specific to older adults, but has international origin, while equations 1, 2, 3, 4, 5 (multiethnic) and 7 are generalized equations, meaning they were generated from a more heterogeneous population in relation to age group and body composition. Another important factor to highlight is the gold standard method used, as all equations in the present study were validated from Hydrostatic Weighing (HW).

Equations 1, 2, 3, 4, 5 and 6 showed high sensitivity and positive predictive value values (i.e. they have an excellent ability to detect obesity when it is present). Only equation 7 showed a low positive predictive value (i.e. it has a low ability to detect obese individuals). It is important to highlight that we adopted the cut-off point of 30% fat to dichotomize between normal and obesity. We did not adopt different cut-off points to test specificity and sensitivity, because according to STREINER and CAIRNEY (2007), changing the cut-off changes the number of erroneous judgments, but will not eliminate the problem. In this analysis, equations 2, 3, 5 and 6 showed agreement values > 90%. This type of analysis does not consider random error, so it is important to emphasize that we must be careful when considering good results.

One of today's major public health problems is the increase in the obese population, so having good detection strategies is a major step towards identification and follow-up. Despite our article presenting some limitations (e.g., sample size, convenience sampling), we believe that the results indicate that the tested equations showed moderate agreement with the gold standard method and that even without skinfolds body fat prediction was adequate.

While body composition studies are not a major focus, the development of low-cost tools for measuring body fat in older adults is crucial Based on the foregoing, we propose conducting new studies with representative and random samples of the elderly population to test the validity and reproducibility of equations that use only simple and easy-to-obtain measures (example: body mass, stature, and circumferences).

Conclusions

Despite the high limits of agreement, all the equations generally showed good levels of validity in different statistics. Even the Bergman et al. (Equation 1), which showed low agreement, had a high positive predictive value. Based on the above, we propose that all equations can be used to measure body composition in older Brazilian women.

Conflicts of interest

The author(s) declare that there are no conflicts of interest concerning this work, authorship, and/or publications of this paper.

References

Agha, M., & Agha, R. (2017). The rising prevalence of obesity: part A: impact on public health. *Int J Surg Oncol (N Y), 2*(7), e17. doi:10.1097/ij9.0000000000000017

Amarya, S., Singh, K., & Sabharwal, M. (2014). Health consequences of obesity in the elderly. *Journal of Clinical Gerontology and Geriatrics, 5*(3), 63-67.

doi:https://doi.org/10.1016/j.jcgg.2014.01.004

Arroyo, P., Lera, L., Sánchez, H., Bunout, D., Santos, J. L., & Albala, C. (2007). Indicadores antropométricos, composición corporal y limitaciones funcionales en ancianos. *Revista médica de Chile, 135*, 846-854.

Bergman, R. N., Stefanovski, D., Buchanan, T. A., Sumner, A. E., Reynolds, J. C., Sebring, N. G., . . . Watanabe, R. M. (2011). A better index of body adiposity. *Obesity (Silver Spring), 19*(5), 1083-1089. doi:10.1038/oby.2011.38.

Colleluori, G., & Villareal, D. T. (2021). Aging, obesity, sarcopenia and the effect of diet and exercise intervention. *Experimental Gerontology*, 155, 111561. doi:https://doi.org/10.1016/j.exger.2021.111561

Da Cruz, I. B. M., Almeida, M. S. C., Schwanke, C. H. A., & Moriguchi, E. H. (2004). Prevalência de obesidade em idosos longevos e sua associação com fatores de risco e morbidades cardiovasculares. *Revista da Associação Médica Brasileira, 50*.

de Onis, M., & Habicht, J. P. (1996). Anthropometric reference data for international use: recommendations from a World Health Organization Expert Committee. *Am J Clin Nutr, 64*(4), 650-658. doi:10.1093/ajcn/64.4.650

Delgado-Gonzalo, R., Parak, J., Tarniceriu, A., Renevey, P., Bertschi, M., & Korhonen, I. (2015). Evaluation of accuracy and reliability of PulseOn optical heart rate monitoring device. *Annu Int Conf IEEE Eng Med Biol Soc, 2015*, 430-433. doi:10.1109/embc.2015.7318391

Deurenberg, P., Weststrate, J. A., & Seidell, J. C. (1991). Body mass index as a measure of body fatness: age- and sex-specific prediction formulas. *British Journal of Nutrition, 65*(2), 105-114. doi:10.1079/BJN19910073

Deurenberg, P., Yap, M., & van Staveren, W. A. (1998). Body mass index and percent body fat: a meta analysis among different ethnic groups. *International Journal of Obesity, 22*(12), 1164-1171. doi:10.1038/sj.ijo.0800741

Duren, D. L., Sherwood, R. J., Czerwinski, S. A., Lee, M., Choh, A. C., Siervogel, R. M., & Cameron Chumlea, W. (2008). Body composition methods: comparisons and interpretation. *J Diabetes Sci Technol, 2*(6), 1139-1146. doi:10.1177/193229680800200623

Fokkema, T., Kooiman, T. J., Krijnen, W. P., CP, V. D. S., & M, D. E. G. (2017). Reliability and Validity of Ten Consumer Activity Trackers Depend on Walking Speed. *Med Sci Sports Exerc, 49*(4), 793-800. doi:10.1249/mss.0000000000001146

Gallagher, D., Visser, M., Sepúlveda, D., Pierson, R. N., Harris, T., & Heymsfield, S. B. (1996). How useful is body mass index for comparison of body fatness across age, sex, and ethnic groups? *Am J Epidemiol, 143*(3), 228-239. doi:10.1093/oxfordjournals.aje.a008733

Gómez-Ambrosi, J., Silva, C., Catalán, V., Rodríguez, A., Galofré, J. C., Escalada, J., Frühbeck, G. (2012). Clinical usefulness of a new equation for estimating body fat. *Diabetes Care, 35*(2), 383-388. doi:10.2337/dc11-1334

Heyward, V. H. (1998). Practical body composition assessment for children, adults, and older adults. *Int J Sport Nutr, 8*(3), 285-307. doi:10.1123/ijsn.8.3.285

Heyward, V. H., & Wagner, D. R. (2004). *Applied body composition assessment* (2nd ed.). Champaign, IL: Human Kinetics.

Kagawa, M., Byrne, N. M., & Hills, A. P. (2008). Comparison of body fat estimation using waist:height ratio using different 'waist' measurements in Australian adults. *Br J Nutr, 100*(5), 1135-1141. doi:10.1017/s0007114508966095

Keller, K., & Engelhardt, M. (2013). Strength and muscle mass loss with aging process. Age and strength loss. *Muscles Ligaments Tendons J, 3*(4), 346-350.

Lean, M. E., Han, T. S., & Deurenberg, P. (1996). Predicting body composition by densitometry from simple anthropometric measurements. *Am J Clin Nutr, 63*(1), 4-14. doi:10.1093/ajcn/63.1.4

Leknessund, O. G. R., Morelli, V. M., Strand, B. H., Hansen, J. B., & Brækkan, S. K. (2022). Hand grip strength and risk of incident venous thromboembolism: The Tromsø study. *Res Pract Thromb Haemost, 6*(7), e12833. doi:10.1002/rth2.12833

Lin, H., Yu, P., Yang, M., Wu, D., Wang, Z., An, J., . . . Deng, N. (2022). Making Specific Plan Improves Physical Activity and Healthy Eating for Community-Dwelling Patients With Chronic Conditions: A Systematic Review and Meta-Analysis. *Front Public Health, 10*, 721223. doi:10.3389/fpubh.2022.721223

Lin, L. I. (1989). A concordance correlation coefficient to evaluate reproducibility. *Biometrics, 45*(1), 255-268.

Marchi-Alves, L. M., Yagui, C. M., Rodrigues, C. S., Mazzo, A., Rangel, E. M. L., & Girão, F. B. (2011). Obesidade infantil ontem e hoje: importância da avaliação antropométrica pelo enfermeiro. *Escola Anna Nery, 15*.

Mastroeni, M. F., Mastroeni, S. S. d. B. S., Erzinger, G. S., & Marucci, M. d. F. N. (2010). Antropometria de idosos residentes no município de Joinville-SC, Brasil. *Revista Brasileira de Geriatria e Gerontologia, 13*.

McBride, G. B. (2005). *A proposal for strength-of-agreement criteria for Lin's Concordance Correlation Coefficient*: NIWA Client Report: HAM2005-062.

Brazilian Association for the Study of Obesity and Metabolic Syndrome (2022). Mapa da Obesidade. Retrieved from https://abeso.org.br/obesidade-e-sindrome-metabolica/mapa-da-obesidade/

Moreira, A. d. J., Nicastro, H., Cordeiro, R. C., Coimbra, P., & Frangella, V. S. (2009). Composição corporal de idosos segundo a antropometria. *Revista Brasileira de Geriatria e Gerontologia, 12*.

Nelson, M. B., Kaminsky, L. A., Dickin, D. C., & Montoye, A. H. (2016). Validity of Consumer-Based Physical Activity Monitors for Specific Activity Types. *Med Sci Sports Exerc, 48*(8), 1619-1628. doi:10.1249/mss.0000000000000933

Nita, M., Ellis, M. A., & Madden, L. V. (2003). Reliability and accuracy of visual estimation of phomopsis leaf blight of strawberry. *Phytopathology, 93*(8), 995-1005. doi:10.1094/PHYTO.2003.93.8.995.

Peña, J. C., Martin-Aleman, W. F., Alberto-Cardozo, L., Castillo-Daza, C. A., Andres-Yanez, C., & Tellez Tinjca, L. A. (2022). Efectos de la secuencia de ejercicios intrasesión del entrenamiento concurrente sobre la composición corporal y la aptitud física de las mujeres mayores (Effects of the Intrasession Exercise Sequence of Concurrent Training on Older Women's Body Compositio. *Retos*, *45*, 760–766. https://doi.org/10.47197/retos.v45i0.92613.

Pleticosic-Ramírez, Y., Mecías Calvo, M., & Navarro-Patón, R. (2024). Efectos de programas de ejercicio físico en la composición corporal, condición física y calidad de vida de personas mayores con sobrepeso u obesidad: una revisión sistemática (Effects of physical exercise programs on body composition, physical fitness and quality of life in older people with overweight or obesity: a systematic review). *Retos*, *56*, 47–62. https://doi.org/10.47197/retos.v56.104052

Rech, C. R., Lima, L. R. A., Cordeiro, B. A., Petroski, E. L., & Vasconcelos, F. d. A. G. d. (2010). Validade de equações antropométricas para a estimativa da gordura corporal em idosos do sul do Brasil. *Revista Brasileira de Cineantropometria &Desempenho Humano, 12*.

Ripka, W. L., Cintra-Andrade, J. H., & Ulbricht, L. (2022). A century of skinfolds for body composition estimation: what we learned? *Revista Brasileira de Cineantropometria &Desempenho Humano, 24*.

Santos, K. T., Santos Júnior, J. C. C., Rocha, S. V., Reis, L. A. , Coqueiro, R. S., & Fernandes, M. H. (2014). Indicadores antropométricos de estado nutricional como preditores de capacidade em idosos. *Revista Brasileira de Medicina do Esporte, 20*.

Scafoglieri, A., Clarys, J. P., Cattrysse, E., & Bautmans, I. (2014). Use of anthropometry for the prediction of regional body tissue distribution in adults: benefits and limitations in clinical practice. *Aging Dis, 5*(6), 373-393. doi:10.14366/AD.2014.0500373

Scafoglieri, A., Van den Broeck, J., Cattrysse, E., Bautmans, I., & Heymsfield, S. B. (2022). Non-linear Associations Between Visceral Adipose Tissue Distribution and Anthropometry-Based Estimates of Visceral Adiposity. *Frontiers in Nutrition, 9*. doi:10.3389/fnut.2022.825630

Silva, D. R. P., Ribeiro, A. S., Pavão, F. H., Ronque, E. R. V., Avelar, A., Silva, A. M., & Cyrino, E. S. (2013). Validade dos métodos para avaliação da gordura corporal em crianças e adolescentes por meio de modelos multicompartimentais: uma revisão sistemática. *Revista da Associação Médica Brasileira, 59*.

Siri, W.E. (1961). Body composition from fluid spaces and density: analysis of methods. *Nutrition*, 9:480-491.

Streiner, D. L., & Cairney, J. (2007). What's under the ROC? An introduction to receiver operating characteristics curves. *Can J Psychiatry, 52*(2), 121-128. doi:10.1177/070674370705200210

Visser, M., van den Heuvel, E., & Deurenberg, P. (1994). Prediction equations for the estimation of body composition in the elderly using anthropometric data. *Br J Nutr, 71*(6), 823-833. doi:10.1079/bjn19940189

Westbury, L. D., Beaudart, C., Bruyère, O., Cauley, J. A., Cawthon, P., Cruz-Jentoft, A. J., . . . Cooper, C. (2023). Recent sarcopenia definitions-prevalence, agreement and mortality associations among men: Findings from population-based cohorts. *J Cachexia Sarcopenia Muscle, 14*(1), 565-575. doi:10.1002/jcsm.13160

Woolcott, O. O., & Bergman, R. N. (2018). Relative fat mass (RFM) as a new estimator of whole-body fat percentage ─ A cross-sectional study in American adult individuals. *Scientific Reports, 8*(1), 10980. doi:10.1038/s41598-018-29362-1

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