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Original Article

AGREEMENT BETWEEN ANTHROPOMETRIC EQUATIONS AND AIR DISPLACEMENT PLETHYSMOGRAPHY FOR PREDICTING BODY FAT IN PEOPLE WITH OVERWEIGHT OR OBESITY

CONCORDÂNCIA ENTRE EQUAÇÕES ANTROPOMÉTRICAS E A PLETISMOGRAFIA POR DESLOCAMENTO DE AR PARA PREDIÇÃO DA GORDURA CORPORAL EM ADULTOS COM SOBREPESO E OBESIDADE

Josiel Gomes Ribeiro[1, 2], Cassiano Ricardo Rech[2], Wagner Jorge Ribeiro Domingues[2], Ewertton de Souza Bezerra[1]

[1] Federal University of Amazonas, Manaus-AM, Brazil.
[2] Federal University of Santa Catarina, Florianópolis-SC, Brazil.

RESUMO

O objetivo deste estudo foi comparar equações antropométricas para estimar a porcentagem de gordura corporal (%GC) em indivíduos com sobrepeso e obesidade, utilizando a pletismografia por deslocamento de ar (ADP). Foram selecionados 451 participantes (mulheres: n=357, idade 41,4 ± 8,91 anos, IMC 34,0 ± 2,52 kg/m²; homens: n=94, idade 42,1 ± 11,3 anos, IMC 35,4 ± 2,26 kg/m²). O %GC foi verificado pela ADP e pelas equações de Tran & Weltman, Visser et al., Deurenberg et al., Lean et al., Gallagher et al. e Gómez-Ambrosi et al. A normalidade foi avaliada pelo teste de Shapiro-Wilk, e o coeficiente de correlação de Pearson (r) foi utilizado para avaliar a relação entre os métodos de composição corporal. A análise de Bland-Altman avaliou a concordância dos resultados. Para homens com sobrepeso, a equação de Deurenberg et al. não mostrou diferença significativa (p=0,186) em relação à ADP, com uma forte correlação (r=0,98) e um erro médio de -2,6 (95%CI -16,1; 10,9). Para as mulheres a concordância foi encontrada apenas para a equação de Lean et al, tanto no grupo de sobrepeso (P=0,916) quanto no de obesidade (P=0,747). São necessárias novas equações para %GC em homens obesos.

Palavras-chave: Envelhecimento. Composição corporal. Estado nutricional. Antropometria. Obesidade.

ABSTRACT

The aim of this study was to compare different anthropometric equations for estimating percentage body fat (%BF) in overweight and obese individuals, using air displacement plethysmography (ADP). A total of 451 participants were selected (women: n=357, age 41.4 ± 8.91 years, BMI 34.0 ± 2.52 kg/m²; men: n=94, age 42.1 ± 11.3 years, BMI 35.4 ± 2.26 kg/m²). The %BF was verified by ADP and by the equations of Tran & Weltman, Visser et al., Deurenberg et al., Lean et al., Gallagher et al., and Gómez-Ambrosi et al. Normality was assessed using the Shapiro-Wilk test. Pearson's correlation coefficient (r) evaluated the relationship between body composition methods, and Bland-Altman analysis assessed result agreement. For overweight men, the Deurenberg et al. equation showed no significant difference (p=0.186) compared to ADP, with a strong correlation (r=0.98) and a mean error of -2.6 (95%CI -16.1; 10.9). In women, agreement was found only for the Lean et al. equation for both overweight (P=0.916) and obese (P=0.747) groups. Other equations lacked agreement with ADP (P>0.05). The Deurenberg et al. equation is recommended for overweight men, while the Lean et al. equation is suggested for overweight and obese women. New anthropometric equations for assessing %BF in obese men is needed

Keywords: Ageing. Body composition. Nutritional status. Anthropometry. Obesity.

Introduction

Body composition[1] assessments are routinely measured in clinical settings and in sport science laboratories. Excess body fat can lead to health problems, such as hypertension, diabetes, and obesity[2]. It is estimated that obesity is responsible for 8% of global mortality[3]. Furthermore, more than half of the global population is overweight[2.]

The Body mass index (BMI) is a frequently used measure to classify overweight and obesity[4.] However, the body mass index does not appear to fully quantify body fat distribution or clearly discriminate between fat mass and fat-free mass indices, overestimating the total body fat of an athlete with a high amount of muscle mass, in addition to the ability to estimate total body fat of an obese individual[4]. Furthermore, the body mass index is also not specific to sex, as although women tend to store more fat mass, while men tend to have more lean mass, both can have the same estimate of body fat when using this measurement strategy[5].

Although the measurement of body fat is necessary for a more accurate assessment of overweight and obesity, this evaluation requires the use of instruments and techniques (e.g., magnetic resonance imaging - MRI, air displacement plethysmography - ADP, computed tomography – CT, and dual energy x-ray absorptiometry - DXA), which have high costs, require trained technicians, and have limited application in field conditions [6-7]. Some recent studies sought to investigate and validate the use of lower cost equipment[8], while other studies investigated the comparison of high-cost equipment with estimation equations[9]. However, these studies do not consider different sexes, or were restricted to women [10], or included healthy young participants without overweight or obesity and a low number of participants in the sample [9].

For this reason, estimating body fat can be challenging, and the development and validation of simpler, cheaper, and non-invasive methods, such as predictive equations to estimate %BF, based on anthropometric measurements (body weight, height, age, and sex) is necessary, so that they can be easily applied in a clinical setting[11]. Therefore, the objective of the current study is to compare different equations for estimating body fat in overweight and obese individuals, considering different sexes.

Methods

Sample

In this cross-sectional study, the evaluations were carried out at the Laboratory for the Study of Human Performance (LEDEHU) of the Faculty of Physical Education and Physiotherapy (FEFF) of the Federal University of Amazonas (UFAM). The inclusion criteria were; participants between 18 and 75 years of age, who were categorized as overweight (25.0 to 29.9 Kg/m2) or obese (>30 Kg/m2), according to the BMI classification suggested by the WHO. Participants with claustrophobia, physical disabilities, or any condition that could alter the individual's hydration status, such as renal or hepatic diseases or the use of medications affecting fluid balance, were excluded. A total of 451 overweight and obese adults were selected, 357 women and 94 men, residents of the urban area of the city of Manaus. The 451 volunteers were recruited by convenience through the Manaus + Healthy project, a pioneering weight loss program conducted between 2016 and 2019 in three editions. During the initial evaluation period of each edition, data collection was performed, including body composition assessment, carried out by LEDEHU/FEFF/UFAM.

The variables analyzed in this study were: chronological age, body mass (BM), height (HT), BMI, %BF obtained by ADP, and %BF obtained by the equations of Tran & Weltman [12] Visser et al.[13] , Deurenberg et al[14]. ,Lean et al. [15],Gallagher et al. [16] and Gómez-Ambrosi et al. [17]. The present study used a secondary database, and no new data were collected directly from human participants. The database employed was fully anonymized, with no individual identification of participants, thereby preserving confidentiality and privacy. According to Resolution No. 510/2016 of the National Health Council, research using exclusively secondary, public, or non-identifiable data does not require review by a Research Ethics Committee (CEP),in addition, the study was conducted in accordance with the Declaration of Helsinki.

Procedures

All measurements were performed by trained evaluators following standardized protocols, and measurement error was minimized through previously calibrated intra- and inter-rater procedures. Missing data and outliers were handled according to pre-established statistical criteria, ensuring consistency of the analysis. Sample size calculation was not performed due to the exploratory, cross-sectional, and retrospective nature of the study, whose primary objective

was the comparative analysis of the accuracy of different methods for estimating body fat percentage in a large sample of adults with overweight and obesity.

Air displacement plethysmography (ADP): Participants attended two laboratory visits, always in the morning between 8:00 a.m. and 12:00 p.m., to ensure consistency in data collection and minimize daily variations in body composition. During each visit, body mass was measured using a digital scale (Tanita Inc., Arlington Heights, IL, USA), and body fat percentage was assessed via air displacement plethysmography (ADP) using the BODPOD® Body Composition System (Life Measurement Instruments, Concord, CA, USA). To standardize environmental conditions and reduce potential sources of error, participants were instructed to avoid food and fluid intake for at least two hours prior to measurements, refrain from smoking or alcohol consumption in the 24 hours preceding the assessment, avoid applying body lotion on the day of measurement, and refrain from intense physical activity in the 24 hours prior to measurements. These procedures ensured that assessments were conducted under standardized conditions, enhancing the reliability of the results and minimizing variations related to external or behavioral factors.The ADP.device was calibrated by calculating the pressure ratio for an empty chamber and a known volume (56,056 l). The scale attached to the device was also calibrated with a known reference (20kg). After receiving an explanation of the procedures, participants entered the ADP wearing minimal clothing. A swimming cap was worn to reduce the volume of hair, and the use of metal objects on the body was prohibited (e.g. earrings, rings, piercings, and so on). Participants remained seated inside the device and at each stage of the ADP assessment the door was opened. The measure adopted too an average of four minutes. During this phase, the participant's gross body volume was determined according to Boyle's law. Due to the difficulty in assessing the lung volume of the participant's, predicted values were used. This procedure did not affect the estimation of body composition [18]. Body density was determined by the pressure and volume range. Finally, %BF was calculated using the Siri equation [19].

Anthropometry: First, the weight and height of the participants were evaluated to obtain the BMI. Subsequently, the circumferences of the right and left arms, chest, waist, abdomen, hip, right thigh, and left thigh were measured [20].

After collecting anthropometric data, body density and fat percentage for both sexes were estimated using the selected anthropometric equations (Table 1) and the %BF results of the reference method were calculated by the Siri equation [19]. The criteria for choosing the predictive equations for analysis were as follows: Equations described and validated in the literature that assess density and percentage of body fat only through anthropometric measurements and that cover the variables in the study database.

Statistical analysis

Data are presented as mean and standard deviation. Data normality was verified by the Shapiro-Wilk test. To assess agreement between body fat percentage (%BF) measured by air displacement plethysmography (ADP) and estimated by anthropometric equations, multiple metrics were employed. Bias was calculated as the mean difference between methods, with its corresponding 95% confidence interval (CI). Agreement was visually inspected and quantified using the 95% Bland-Altman[21] limits of agreement (LoA), with 95% CIs calculated as described by Carkeet[22]. The presence of proportional bias was investigated using simple linear regression, with the differences between methods as the dependent variable and the means of the two methods as the independent variable. Additionally, agreement was evaluated using Lin's Concordance Correlation Coefficient (CCC)[23] and the Intraclass Correlation Coefficient (ICC)[24] for absolute agreement (two-way random effects model, absolute agreement), both with their respective 95% CIs. Pearson's correlation coefficient (r) was reported only as a descriptive

measure of the linear association between methods. All analyses were performed using R software (version 4.2.1), with a significance level set at $p < 0.05$.

Table 1 - Predictive equations for estimating density (DC) and body fat (%BF), proposed by several authors and used in the present study

Gender	Author	Equation	Age
Women (n=482)	*Tran & Weltman /1989*	*D= 1,168297 – 10,002824 (PABD) + 0,0000122098 (PABD)2 – 0,000733128 (PQU) + 10,000510477 (EST) – 0,000216161 (ID)*	*15 a 79 years old*
Elderly Men and Women (n=204)	*Visser, et al. (1994)*	*D= 0,0226 x (Ŧ) – 0,0022(BMI) + 1,0605*	*60 a 87 years old*
Men e Women (n=1229)	*Deurenberg, et al. (1991)*	*%F= 1,2(BMI) + 0,23(ID) – 10,8(Ŧ) – 5,4*	*07 a 83 years old*
Women (n=84)	*Lean et al 1996*	%BF= 1,21 x BMI + 0,262 x age – 6,7	18 a 64 years old
Men (n=63)	*Lean et al 1996*	*%BF = (1,33 x BMI) + (0,236 x age) – 20,2*	*18 a 64 years old*
Men e Women (n=1626)	*Gallagher et al 2000*	*%BF = 76 – 1097,8 x (1/BMI) – 20,6 x sex + 0,053 x age in years old + 95*	*20 a 94 years old*
Men e Women (n=6510)	*Gómez-Ambrosi et al, CUN-BAE 2012*	*%BF= – 44.988 + (0,503 x age) + (10,689 x gender) + (3.172 x BMI) – (0,026 x BMI²) + (0,181 x BMI x sex) – (0,02 x BMI x idade) – (0,005 x BMI² x sex) + (0,00021 x BMI² x age)*	*18 a 80 years old*

Note: %BF (body fat percentage) D (density) (PABD=waist circumference) (PQU= hip circumference) (PIL=iliac circumference) (BM= body mass) EST= height, ID= age, PANT= forearm circumference, BMI= body mass index,Ŧ=constant for sex (female= 0 and male= 1)
Source: The authors

Results

Data on the characteristics of the participants are presented in table 2.

Table 2. Characteristics of a people with overweight and obesity. Manaus, Brazil 2018 (n=451).

Variables	Overweight[a] (n=130)			Obesity[b] (n=321)		
	Men	**Women**	**p-value**	**Men**	**Women**	**p-value**
Age (yrs)	42.1 ± 11.3	41.4 ± 8.91	0.80	42.1 ± 10.5	40.3 ± 10.1	0.173
Height (m)	1.73 ± 0.07	1.60 ± 0.06	<0.001	1.73 ± 0.05	1.60 ± 0.06	<0.001
Weight (kg)	85.7 ± 8.54	72.3 ± 7.03	<0.001	106.5±9.73	87.6 ± 10.7	<0.001
WC (cm)	97.5 ± 6.07	84.0 ± 6.76	<0.001	107.7 ±8.47	93.0 ± 7.82	<0.001
BMI (kg.m^2)	28.4 ± 1.43	27.9 ± 1.35	<0.233	35.4 ± 2.26	34.0 ± 2.52	<0.001
% BF$_{ADP}$	25.2 ± 3.90	28.1 ± 6.03	0.083	39.8 ± 7.99	39.5 ± 7.27	0.721
FFM$_{ADP\ (kg)}$	57.9± 8.73	46.3 ± 6.79	<0.001	64.8 ± 10.8	48.6 ± 7.59	<0.001

Note: Mean ± standard error of mean. BMI - Body Mass Index; [a]BMI between 25 and 29.9 kg.m^2; [b]BMI higher than 30 kg.m^2; ADP – Air Displacement Plethysmography; FFM – Free-fat mass.
Source: The authors

Among overweight men, the Bland-Altman analysis indicated a mean error of -2.6, with limits of agreement ranging from -16.1 to 10.9 (Figure 1A). In women, the Lean equation indicated a mean error of -0.1 and limits from -11.3 to 11.2 in the overweight group, and in the obese group (r = 0.32), a mean error of 0.1 with limits from -10.2 to 10.4 (Figures 1B and 1C).

The agreement analyses (Table 3) revealed that for overweight men, the Deurenberg et al. equation showed the lowest bias (2.57, 95% CI [-1.41; 6.55]), although a proportional bias was identified (p=0.184). For obese men, no equation demonstrated good agreement, with the Deurenberg et al14. equation still showing the lowest bias (2.24, 95% CI [1.15; 3.34]), but with a strong proportional bias (p<0.001. For overweight women, the Lean et al. equation showed the lowest bias (0.06, 95% CI [-1.00; 1.12]), but with a significant proportional bias (p<0.001). Similarly, for obese women, the Lean et al. equation also presented the lowest bias (-0.11, 95% CI [-0.78; 0.56]), but maintained a proportional bias (p<0.001) (. The CCC and ICC values corroborate these findings, indicating weak to moderate agreement in most comparisons.

Table 3: Agreement Analysis between Anthropometric Equations and Plethysmography (ADP)
Overweight Men

Equation	Bias (95% CI)	Lower LoA (95% CI)	Upper LoA (95% CI)	Prop. Bias (p; slope)	CCC (95% CI)	ICC (95% CI)
Tran & Weltman	9.46 [6.37; 12.56]	-1.04 [-6.40; 4.32]	19.97 [14.61; 25.33]	0.0 (1.863)	0.013 [-0.521; 0.540]	0.013 [-0.475; 0.551]
Visser et al.	8.33 [5.16; 11.50]	-2.43 [-7.93; 3.06]	19.1 [13.60; 24.59]	0.0 (2.012)	-0.002 [-0.532; 0.529]	-0.002 [-0.519; 0.509]
Deurenberg et al.	2.57 [-1.41; 6.55]	-10.94 [-17.84; -4.05]	16.09 [9.19; 22.98]	0.184 (0.825)	-0.079 [-0.585; 0.472]	-0.084 [-0.578; 0.444]
Lean et al.	-8.56 [-12.65; -4.47]	-22.43 [-29.51; -15.35]	5.32 [-1.76; 12.40]	0.302 (0.646)	-0.032 [-0.553; 0.507]	-0.033 [-0.573; 0.450]
Gallagher et al.	-13.79 [-19.16; -8.43]	-32.0 [-41.29; -22.71]	4.41 [-4.88; 13.70]	0.316 (-0.592)	-0.007 [-0.536; 0.525]	-0.007 [-0.531; 0.496]

Obese Men

Equation	Bias (95% CI)	Lower LoA (95% CI)	Upper LoA (95% CI)	Prop. Bias (p; slope)	CCC (95% CI)	ICC (95% CI)
Tran & Weltman	17.45 [16.27; 18.64]	7.02 [4.97; 9.07]	27.89 [25.84; 29.94]	0.0 (1.9)	0.002 [-0.218; 0.221]	0.002 [-0.198; 0.239]
Visser et al.	16.12 [14.95; 17.30]	5.75 [3.70; 7.79]	26.5 [24.46; 28.54]	0.0 (1.963)	0.002 [-0.218; 0.221]	0.002 [-0.201; 0.235]
Deurenberg et al.	2.24 [1.15; 3.34]	-7.4 [-9.30; -5.51]	11.89 [10.00; 13.79]	0.0 (0.493)	0.381 [0.176; 0.554]	0.383 [0.229; 0.590]
Lean et al.	-8.96 [-10.08; -7.84]	-18.82 [-20.76; -16.88]	0.9 [-1.04; 2.84]	0.003 (0.41)	0.151 [-0.071; 0.359]	0.152 [0.229; 0.590]
Gallagher et al.	-11.29 [-12.84; -9.75]	-24.89 [-27.57; -22.22]	2.31 [-0.37; 4.98]	0.121 (-0.257)	0.104 [-0.119; 0.316]	0.104 [0.084; 0.484]

Overweight Women

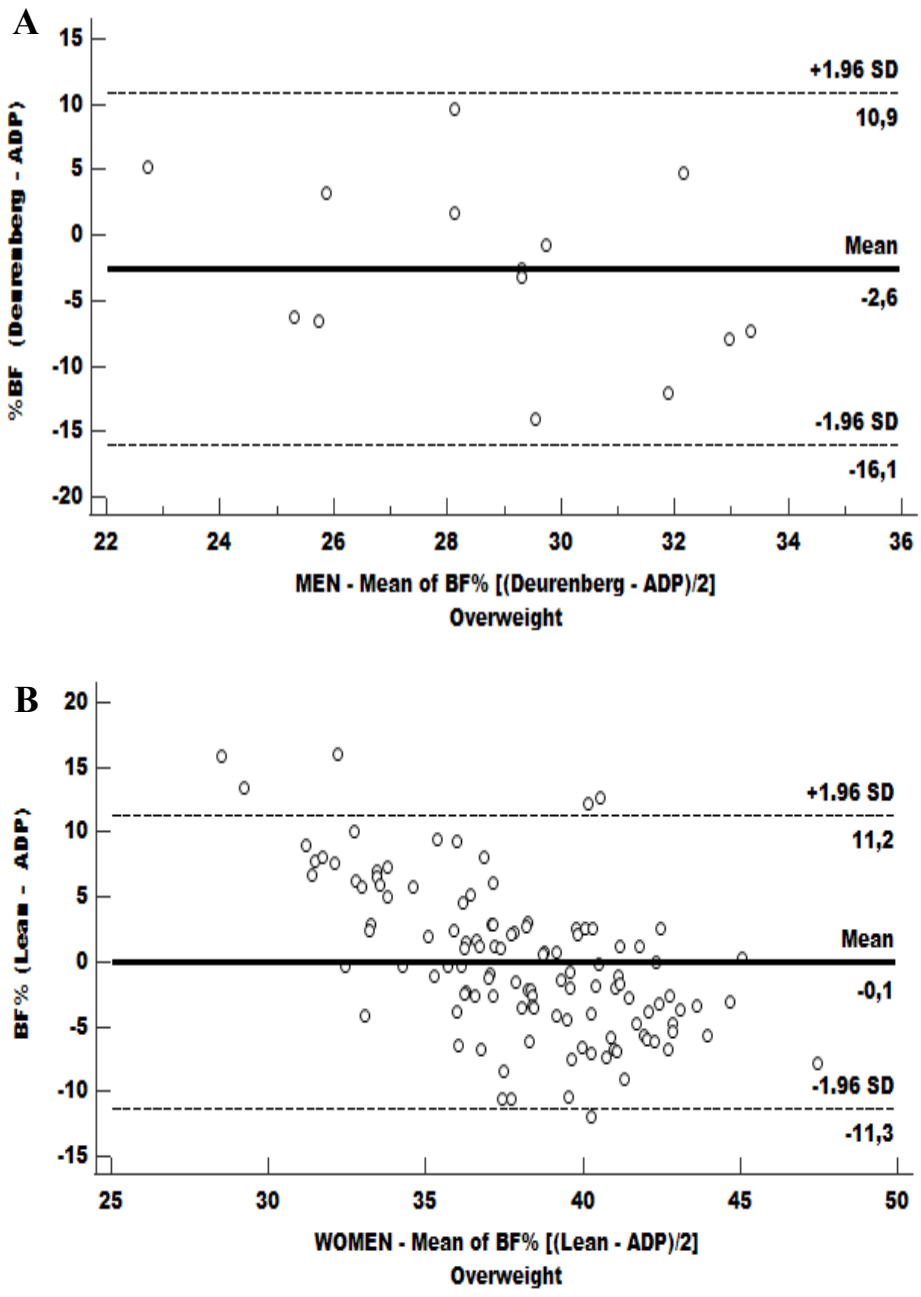
Equation	Bias (95% CI)	Lower LoA (95% CI)	Upper LoA (95% CI)	Prop. Bias (p; slope)	CCC (95% CI)	ICC (95% CI)
Tran & Weltman	17.03 [15.95; 18.10]	5.59 [3.73; 7.44]	28.47 [26.61; 30.32]	0.0 (1.903)	0.00 1 [-0.181; 0.184]	0.001 [-0.169; 0.194]
Visser et al.	15.74 [14.68; 16.81]	4.38 [2.53; 6.23]	27.11 [25.26; 28.95]	0.0 (1.983)	0.001 [-0.181; 0.183]	0.001 [-0.173; 0.190]
Deurenberg et al.	0.36 [-0.68; 1.41]	-10.74 [-12.55; -8.94]	11.47 [9.67; 13.28]	0.0 (1.066)	0.218 [0.037; 0.385]	0.219 [0.038; 0.385]
Lean et al.	0.06 [-1.00; 1.12]	-11.23 [-13.06; -9.39]	11.34 [9.51; 13.17]	0.0 (0.979)	0.219 [0.039; 0.386]	0.221 [0.039; 0.386]
Gallagher et al.	0.68 [-0.32; 1.68]	-9.98 [-11.72; -8.25]	11.34 [9.61; 13.08]	0.0 (1.412)	0.192 [0.011; 0.362]	0.194 [0.014; 0.364]

Obese Women

Equation	Bias (95% CI)	Lower LoA (95% CI)	Upper LoA (95% CI)	Prop. Bias (p; slope)	CCC (95% CI)	ICC (95% CI)
Tran & Weltman	23.97 [23.33; 24.61]	14.07 [12.96; 15.18]	33.87 [32.76; 34.98]	0.0 (1.878)	0.001 [-0.126; 0.127]	0.001 [-0.107; 0.145]
Visser et al.	22.39 [21.75; 23.02]	12.59 [11.50; 13.69]	32.18 [31.08; 33.28]	0.0 (1.956)	0.001 [-0.125; 0.127]	0.001 [-0.105; 0.147]
Deurenberg et al.	0.22 [-0.43; 0.87]	-9.82 [-10.94; -8.69]	10.26 [9.13; 11.39]	0.0 (0.501)	0.315 [0.197; 0.425]	0.316 [0.197; 0.425]
Lean et al.	-0.11 [-0.78; 0.56]	-10.43 [-11.59; -9.27]	10.21 [9.05; 11.37]	0.0 (0.428)	0.304 [0.184; 0.414]	0.305 [0.185; 0.414]
Gallagher et al.	2.32 [1.73; 2.91]	-6.79 [-7.82; -5.77]	11.44 [10.42; 12.46]	0.0 (1.184)	0.218 [0.095; 0.336]	0.219 [0.137; 0.373]

Note: Bias (95% CI), lower and upper limits of agreement (LoA, 95% CI), proportional bias (p; slope), concordance correlation coefficient (CCC, 95% CI), and intraclass correlation coefficient (ICC, 95% CI) between methods
Source: The author.s

To facilitate the visualization of agreement between the evaluated methods, Figure 1 presents the Bland–Altman plots for the equations that demonstrated the best performance in each analyzed subgroup. The graphical representation allows observation of the mean bias (mean difference between methods) and the 95% limits of agreement, highlighting the magnitude and dispersion of differences between air displacement plethysmography (ADP) and the anthropometric equations used to estimate %BF in overweight and obese men and women.



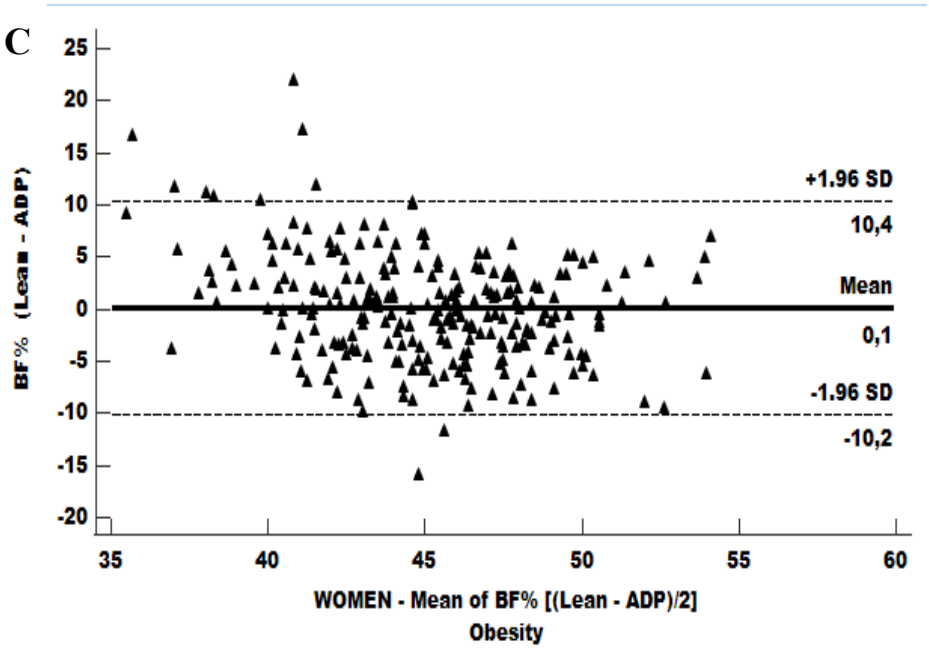


Figure 1- Agreement between different anthropometric equations for predicting %BF in overweight and obese men and women (circles represent overweight and triangles represent obesity). Deurenberg et al. [14] equation for overweight men (**panel A**); Lean et al.[15] equation for overweight and obese women (panels **B and C**).
Source: The author's.

Discussion

The current study focused on analyzing the agreement of different equations for predicting body fat percentage (%BF) in overweight and obese people, considering different sexes. The selected equations use easy-to-collect anthropometric measurements that can be applied in health services and clinical practices which do not possess more accurate equipment for this measurement, since %BF information can help identify health problems such as overweight and obesity[2]. Previous studies show that equations have been widely used and applied to estimate body fat in men and women[25-26]. The sample included participants of both sexes, with a majority of women. This trend would be expected, since research shows that women are more likely to seek health care services than men [27].

The results of our study indicate that the Deurenberg et al. equation [14] had a low margin of error with a high accuracy rate for overweight men (see details in Table 3). Corroborating this finding, Shannon et al.[28] compared body composition prediction equations with air displacement plethysmography (ADP) in overweight and obese Caucasian men residing in the United States, and showed no significant difference ($p>0.05$) between the ADP and Deurenberg et al. equation [14]. Although in Brazil there is a scarcity of studies that compare the ADP with the Deurenberg et al. equation [14] in overweight and obese men in the southern region, Martins et al.[29] compared different equations for estimating body fat in individuals of both sexes, aged between 35 and 68 years, with overweight and obesity, using dual-energy x-ray absorptiometry (DXA) as a reference method. The authors found a high value of correlation ($r=0.86$) between the Deurenberg et al equation[14] and the reference method (DXA), and through the Bland and Altman scatterplot [21], it was possible to verify concordance, with excellent mean values of -0.1 (95%CI= -7.8; 7.5%). In agreement with the findings of Martins et al.,[29] in our study, for overweight men, the Deurenberg et al. equation[14] did not differ statistically from the ADP ($p=0.186$) in addition to showing a strong correlation between the methods ($r=0.98$; $p<0.01$),

and agreement through Bland & Altman [21], with a mean error of 2.6% (95%CI = -16.1; 10.9%).

When we compare the results of the present study with that of Martins et al. [29], it should be noted that their findings were not stratified by sex, despite being similar to this study in terms of BMI category and age group, including individuals in the same age range (35 to 68 years, n=318). However, the results of these studies demonstrate that the Deurenberg et al.[14] may have good applicability for individuals classified as overweight both in the southern region of Brazil, as well as residents of the city of Manaus, Amazonas.

An additional noteworthy aspect of our findings is that, for overweight and obese women, the Lean et al. equation [15] exhibited no statistically significant difference ($p > 0.05$) when compared to the reference method, i.e., air displacement plethysmography (ADP). Specifically, among overweight women, our study revealed a correlation of 0.27 and a mean error of -0.1% (95%CI = -11.3; 11.2%) for the Lean equation. Similarly, for women categorized as obese, an r=0.31 and a mean error of -0.1% were observed (95%CI = -10.2; 10.4%). For overweight women, our study showed a correlation of 0.27 and a mean error of -0.1% (95%CI = -11.3; 11.2%) for the Lean equation, while for women classified as obese an r=0.31 and a mean error of -0.1% were found (95%CI = -10.2; 10.4%). For the Lean et al. equation [15], no studies were found that compared their results with the ADP, a fact that limits the comparison of data obtained in this study.

However, in their original study in Europe, Lean et al. [15], developed body composition prediction equations, using hydrostatic weighing and easily obtainable anthropometric variables, such as body perimeter and BMI, which make it easy to apply. In their study, 63 men and 84 women were recruited, with average ages of 40.1 and 39.9 years, respectively, which corroborates, in part, with the data of the present study. Furthermore, the authors reported that equations using the simple measures of waist circumference and age showed remarkable robustness for the prediction of body fat, with low error and free of bias by age or fat, and therefore, these measures can be used for clinical and epidemiological purposes, thereby avoiding errors associated with fat distribution[15].

The findings elucidated in the current study underscore the challenges associated with devising cost-effective and widely accessible methodologies for assessing relative fat levels in individuals with overweight and obesity within clinical and population health routines. This difficulty arises, in part, from the limited representation of individuals with these conditions in the development and validation samples of the equations, consequently constraining the accuracy of their estimates for this variable. Nonetheless, two equations emerged as viable options, demonstrating validity and applicability in public health services, particularly in contexts where more sophisticated resources may be scarce[30]. Furthermore, these equations align with the stipulations of the Food and Nutrition Surveillance System - SISVAN, for nutritional assessment. They adhere to criteria such as being economically feasible, straightforward to implement, offering ease of application, standardized protocols, and substantial analytical potential, while also being non-invasive[31].

Despite the advantages presented by the anthropometric equations in the current study, caution is warranted when analyzing the predictive values of body fat percentage (%BF). These equations exhibit certain limitations attributable to inter-individual variability, manifesting disparities in body composition across factors such as gender, ethnicity, age, and level of physical activity. Such variations contribute to significant inequalities in body composition patterns. Another limitation of this study was the use of predicted thoracic gas volume (TGV), rather than directly measured values, for the calculation of body density by plethysmography. Literature indicates that using predicted TGV can introduce systematic bias in the estimation of body fat percentage. Studies show that in adults, predicted TGV tends to underestimate measured TGV, resulting in overestimation of body density and consequently underestimation of body fat percentage. The magnitude of this bias may vary, but some studies report differences

of up to 2–3% in body fat percentage[32]. Although we used the device's internal prediction equation, which is common practice, we acknowledge that direct TGV measurement would have increased the accuracy of the reference method. Additionally, it is important to recognize the inherent limitations of the Siri equation, used to convert body density into body fat percentage. The equation assumes a constant density for fat-free mass (1.100 g/cm^3). However, the composition of fat-free mass (especially the proportion of water and minerals) can vary significantly in individuals with obesity, altering its actual density. In people with obesity, the density of fat-free mass tends to be lower than the constant value assumed by Siri, which may lead to overestimation of body fat percentage. Although the Siri equation remains the standard for air displacement plethysmography, using population-specific conversion equations could refine estimates in the future.[19].

Hence, as evidenced in this study, particular attention should be directed towards the formulation of an equation specifically tailored to characterize %BF and %FFM in obese men. None of the equations examined herein yielded accurate results, showcasing substantial margins of error within this demographic. This underscores the imperative for a more nuanced and precise equation for accurately assessing body composition in individuals with obesity.

Conclusion

In summary, among anthropometric equations exclusively reliant on perimetry for %BF assessment, the equation devised by Deurenberg et al.[14] demonstrates concordance when applied to overweight men. Furthermore, the equation formulated by Lean et al.[15] exhibits suitability for application in overweight and obese women. Health professionals are encouraged to employ these equations for the assessment and ongoing monitoring of %BF in their clients/patients.

Furthermore, our study suggests the prospect of future investigations proposing a novel equation grounded in anthropometric measurements for predicting %BF in men with obesity residing in the Manaus city region. This avenue of research could contribute to refining and tailoring predictive models for specific demographic groups, enhancing the precision of %BF assessments in this population.

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CRediT author statement
Josiel Gomes Ribeiro: Conceptualization, Methodology, Investigation, Writing – original draft;
Cassiano Ricardo Rech: Formal analysis, Data curation, Validation;
Wagner Domingues Oliveira: Writing – review & editing, Visualization;
Ewertton de Souza Bezerra: Conceptualization, Investigation, Supervision, Project administration

ORCID
Josiel Gomes Ribeiro: https://orcid.org/0000-0002-4178-7917
Cassino Ricardo Rech: https://orcid.org/0000-0002-9647-3448
Wagner Jorge Ribeiro Domingues: https://orcid.org/0000-0003-1638-6465
Ewertton de Souza Bezerra: https://orcid.org/0000-0003-4397-1715

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Corresponding author: Josiel Gomes Ribeiro, josielg.ribeiroo@gmail.com