Rev Bras Cineantropom Desempenho Hum

original article

https://doi.org/10.1590/1980-0037.2022v24e84048

Classification of nutritional status by fat mass index: does the measurement tool matter?

Classificação do estado nutricional pelo índice de massa gorda: o instrumento de medição importa?

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Abstract – Assessment of the Nutritional Status (NS) allows screening for malnutrition and obesity, conditions associated with chronic non-communicable diseases. The fat mass index (FMI) stands out concerning traditional NS indicators. However, proposals that define thresholds for FMI are not sensitive to discriminate extreme cases (degrees of obesity or thinness). Only one proposal (NHANES), determined by total body densitometry (DXA), established eight categories of NS classification (FMI). However, DXA is expensive and not always clinically available. Our study aims to test the validity of the NHANES method using electrical bioimpedance (BIA) and skinfold thickness (ST) to classify NS. The FMI of 135 (69 women) university students aged 18 to 30 years old was determined using DXA, BIA, and ST. The agreement between the instruments (Bland-Altman) and the agreement coefficient in the NS classifications (Chi-square and Kappa index) were tested. The agreement test against DXA indicated that ST underestimated the FMI (-1.9 kg/m²) for both sexes and BIA in women (-2.0 kg/m²). However, BIA overestimated FMI (1.4 kg/m²) in men, although with less bias. There was no agreement between the NS classifications (NHANES) by FMI between DXA and BIA, or DXA and ST. The exception occurred between DXA and BIA in men who showed a slightly better consensus, considered "fair" (k = 0.214; p = 0.001). In conclusion, ST and BIA did not show enough agreement to replace DXA for NS classification, within NHANES thresholds. The FMI measurement tools for the NHANES classification of the categories of NS matters.

Keywords: Adiposity; Anthropometry; Body composition; Body mass index; Electric impedance.

Resumo – *Avaliar o Estado Nutricional (EN) permite rastrear desnutrição e obesidade, condições associadas a doenças crônicas não transmissíveis. O índice de massa gorda (IMG) destaca-se em relação aos indicadores tradicionais de EN. No entanto, propostas que definem limiares para IMG não são sensíveis para discriminar casos extremos (graus de obesidade ou magreza). Apenas uma proposta (NHANES) estabeleceu oito categorias de classificação EN (IMG), mas foi determinada por densitometria corporal total (DXA). Porém, DXA é caro e nem sempre disponível. O objetivo foi testar a validade do método NHANES usando bioimpedância elétrica (BIA) e dobras cutâneas (DOCs) para classificar o EN. O IMG de 135 (69 mulheres) universitários com idade entre 18 e 30 anos foi obtido por DXA, BIA e DOCs. A concordância foi testada entre os instrumentos (Bland-Altman) e classificações de EN (Qui quadrado e índice Kappa). O teste de concordância com a DXA indicou as DOCs subestimarem o IMG (-1,9 kg/m²) para ambos os sexos e a BIA em mulheres (-2,0 kg/m²). No entanto, as BIA superestimaram o IMG (1,4 kg/m²) nos homens, embora com menos viés. Não houve concordância entre as classificações de EN (NHANES) pelo IMG entre DXA e BIA/DOCs. A exceção ocorreu entre DXA e BIA em homens que apresentaram concordância "razoável" (k = 0,214; p = 0,001). Em conclusão, DOCs e BIA não mostraram concordância suficiente para substituir DXA pela classificação de EN, dentro dos limites NHANES. As ferramentas diferem para medir IMG e classificar categorias de EN (NHANES).*

Palavras-chave: *Adiposidade; Antropometria; Composição corporal; Índice de massa corporal; Impedância elétrica.*

Received: September 23, 2021
Accepted: March 13, 2022

How to cite this article
Borges FG, Abdalla PP, Alves TC, Venturini ACR, Santos AP, Tasinafo Júnior MF, Aznar S, Mota J, Machado DRL. Classification of nutritional status by fat mass index: does the measurement tool matter? Rev Bras Cineantropom Desempenho Hum 2022, 24:e84048. DOI: https://doi.org/10.1590/1980-0037.2022v24e84048

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INTRODUCTION

Nutritional status (NS) assessment is useful for weight (Wt) control and enables mapping malnutrition and obesity. The increase in overweight and obesity rates across the planet is a cause for concern. This scenario impacts public health given a direct association with the development risk of chronic non-communicable diseases[1]. The body mass index (BMI) is the most popular resource used for epidemiological monitoring of NS. However, BMI is not sensitive for Wt deviation due to excess or deficit in fat mass (FM) or fat-free mass (FFM), under/overestimating NS classification[2]. Another NS assessment is the fat mass percentage (%FM), which also presents biases if stature (Ht) is not considered. Subjects with similar Wt and %FM values, with different Ht, may present a different NS classification[2]. Thus, the fat mass index (FMI [kg/m^2]) appears as an alternative, since distinguishes FM from FFM and is sensitive to the FM distribution related to Ht[2,3]. Additionally, it points to greater sensitivity as a health-disease indicator for metabolic syndrome[4], hypertension[5,] and cardiometabolic risk[6]. FMI calculation requires the measurement of FM, by DXA or more accessible instruments such as anthropometry through skinfolds thickness (ST) or electrical bioimpedance (BIA)[7].

NS classification proposals by FMI usually consider percentiles, sometimes with normal ranges[8,9]. However, they do not classify extreme cases of obesity or thinness. Only National Health and Nutrition Examination Survey (NHANES)[7] proposal established thresholds analogous to BMI (eight NS classifications). So far, this proposal is valid only for Korea's population (KNHANES IV)[10]. Furthermore, that proposal has no validity tested for clinical practice instruments (BIA and ST), since the cutoff points originated from DXA[7]. Therefore, could the proposed NS classification by FMI derived from DXA be applied with BIA and ST? The study hypothesis considered that NS classification no differs between instruments. Although the FMI absolute values of each instrument are not identical, the classification will correspond to the same NS range. Thus, this study aimed to test the concurrent validity between BIA, ST, and DXA for the NS classification by FMI (NHANES) in young adults.

METHODS

Study design and sample

This is a cross-sectional design study. The University's Ethics and Research Committee authorized the research (CAAE 03471118.9.0000.5659) according to the World Medical Association and the Helsinki Declaration. The sample is non-probabilistic, for convenience, composed of 135 university students aged 18 to 30 years old of both sexes (69 women). Individuals without diagnoses of diseases; who did not use drugs that alter metabolism or body composition; who did not have amputated body parts; non-athletes or with physical exercise less than 10 hours/week were included. Cases with some personal or clinical impairment (diseases, personal accidents); withdrawal or did not complete all stages of the study were excluded.

The data collections were performed (10/2016 to 06/2017) at the university hospital, always in the morning to avoid circadian variations. All individuals received the instructions for exams[11]. Initially, they answered a questionnaire on general health status and self-declaration of ethnicity; then they performed the anthropometric measurements and the other exams.

Body measurements

The Ht (m) and Wt (kg) measurements were performed according to recommendations[12], with a fixed wall stadiometer and a digital scale (Filizola® Model ID 1500), respectively. Then, the BMI (kg/m^2) was calculated.

FM and FFM (kg) were determined using three instruments: DXA (GE Medical Systems Lunar scanner, Prodigy Advance, encore software version 13.60 in a linear fan-beam scanner); BIA (tetrapolar type, Biodynamics®, model BIA 450) according to the manufacturers' guidelines; and ST (PrimeMed® calliper, Prime Vision DGi model). DXA supplied directly the FM_{DXA} and FFM_{DXA} using a two-component approach (2-C). We calculate FFM_{BIA} using the equations[13] and body density by ST using generalized equations for men[14] and women[15]. The $\%FM_{ST}$ was determined as well as FM_{ST}, FFM_{ST} and FM_{BIA}, by their respective relationships (2-C) with the BM[16].

Test-retest of 11 individuals verifies the reliability of the DXA measurements. The coefficient of variation for lean soft tissue, FM, and bone mineral content was 0.8%, 1.6%, and 1.6%, respectively. The ST technical error of measurements (TEM) was within the acceptable limits for experienced evaluators (<5%)[17].

FMI and FFMI have obtained from the Vanitallie et al.[2] equations with FM and FFM measured by the three instruments. We establish the NS classification in categories for BMI, $\%FM_{DXA}$[18], and FMI[7]. The NHANES[7] reference values were adopted for the NS classifications by FMI for the three instruments.

Statistical analysis

We reviewed the data by double typing and exploratory analysis for error detection. We use parametric statistics when comparing continuous variables, considering the central limit theorem[19]. Differences between sexes were checked by t-test. We compared visually NS indicators (BMI, $\%FM_{DXA}$, and FMI_{DXA}) with an adaptation of Hattori's chart[20]. The adaptation involved the addition of the NS categories classification for each indicator (BMI, $\%FM_{DXA}$ and FMI_{DXA}), expressed in the NCSS 2020 statistical analysis software (version 20.0.3). We verified the agreement of the FMI absolute values between BIA and ST and the reference (DXA) by the Bland Altman test and the combinations of NS from FMI_{BIA}, FMI_{ST}, and FMI_{DXA} by cross-tabulation and chi-square. The reproducibility of the classifications by the Kappa coefficient followed the classification by Landis and Koch[21]. SPSS 20.0 and MedCalc 15.2 packages were used, with significance previously established (α=5%).

RESULTS

Most individuals (78.5%) were Caucasians, followed by Spanish (10.4%), Asian (3%), and African (2.2%). Nobody declared themselves indigenous while 5.9% did not declare an ethnic class. Regarding lifestyle, only 20.7% declared themselves sedentary (17 women and 11 men) and 6.7% of the total were smokers (four women and five men). Table 1 presents the descriptive statistics and differences between sexes.

Table 1. Comparison of anthropometric variables and indicators of body composition between genders.

	Unit	Female (n=69)			Male (n=66)			Diferences test	
		Mean	SD	CI 95% Lower to Upper	Mean	SD	CI 95% Lower to Upper	t	p
Age	Years	23.9	3.4	23.1 to 24.8	24.5	3.6	23.6 to 25.4	-0.947	0.346
Stature	m	1.7	0.1	1.7 to 1.7	1.8	0.1	1.8 to 1.8	-10.169	<0.001
Wt	Kg	59.7	8.6	57.6 to 61.7	75.4	12.1	72.4 to 78.4	-8.671	<0.001
BMI	kg/m2	21.7	2.8	21.0 to 22.3	23.8	3.2	23.0 to 24.6	-4.173	<0.001
DXA									
FM_{DXA}	Kg	20.2	6.8	18.6 to 21.9	15.3	8.5	13.2 to 17.4	3.725	<0.001
FFM_{DXA}	Kg	39.4	4.0	38.5 to 40.4	60.1	6.9	58.4 to 61.8	-21.292	<0.001
$\%FM_{DXA}$	%	33.2	7.1	31.5 to 34.9	19.4	8.1	17.4 to 21.4	10.561	<0.001
FMI_{DXA}	kg/m2	7.3	2.3	6.8 to 7.9	4.8	2.6	4.2 to 5.4	5.945	<0.001
$FFMI_{DXA}$	kg/m2	14.3	1.3	14.0 a 14.6	19.0	1.7	18.6 to 19.4	-18.046	<0.001
BIA									
FM_{BIA}	Kg	14.6	1.5	14.3 to 15.0	19.6	2.9	18.9 to 20.4	-12.557	<0.001
FFM_{BIA}	Kg	45.0	8.0	43.1 to 47.0	55.8	9.6	53.4 to 58.1	-7.029	<0.001
$\%FM_{BIA}$	%	24.9	3.4	24.1 to 25.7	26.2	2.0	25.7 to 26.6	-2.766	0.007
FMI_{BIA}	kg/m2	5.3	0.5	5.2 to 5.4	6.2	0.7	6.0 to 6.4	-8.374	<0.001
$FFMI_{BIA}$	kg/m2	16.3	2.7	15.7 to 17.0	17.6	2.6	17.0 to 18.3	-2.799	0.006
ST									
FM_{ST}	Kg	15.0	5.1	13.8 to 16.20	9.4	6.0	7.9 to 10.9	5.799	<0.001
FFM_{ST}	Kg	44.7	4.9	43.5 to 45.9	66.0	8.0	64.1 to 68.0	-18.662	<0.001
$\%FM_{ST}$	%	24.6	5.6	23.3 to 26.0	11.8	5.8	10.4 to 13.2	13.061	<0.001
FMI_{ST}	kg/m2	5.4	1.8	5.0 to 5.9	3.0	1.8	2.5 to 3.4	7.967	<0.001
$FFMI_{ST}$	kg/m2	16.2	1.5	15.9 to 16.6	20.9	2.0	20.4 to 21.4	-15.746	<0.001

Note. BIA: electrical bioimpedance; Wt: weight; BMI: body mass index; CI: confidence interval; DXA: dual-energy X-ray absorptiometry; FM: fat mass; FMI: fat mass index; FFM: fat-free mass; FFMI: fat-free mass index; Kg: kilograms; Kg/m²: kilogram per square meter; m: meters; SD: standard deviation; ST: skinfolds thickness; %FM: percentage of fat mass.

Genders were significantly different for all comparisons, except for age. Men had higher muscle indicators Wt (FFM and FFMI), BMI, and FM per BIA (FM_{BIA}, $FMI_{BIA,}$ and $\%FM_{BIA}$) than women for the three instruments. On the other hand, women showed higher fat indicators ($\%FM_{DXA}$, $\%FM_{ST}$, FM_{DXA}, FM_{ST},FMI_{DXA}, and FMI_{ST}).

Figure 1 shows the comparison for each sex between NS classification according to BMI, $\%FM_{DXA}$[18], and FMI_{DXA}[7]. Figure 1 illustrates the differences between $FFMI_{DXA}$ and FMI_{DXA} between the sexes (p<0.001; Table 1) with a greater concentration of dispersion in the upper left quadrant for females and in the lower right quadrant for males. Men presented higher $FFMI_{DXA}$ while women had higher FMI_{DXA}. In the women's NS classification, "normal" was more frequent, whose variation was 76.8% (BMI), 53.6% ($\%FM_{DXA}$), and 63.8% (FMI_{DXA}). "Thinness" cases by BMI (11.6%), $\%FM_{DXA}$ (17.4%) and FMI_{DXA} (11.8%) were smaller than "overweight" by BMI (11.6%), $\%FM_{DXA}$ (18.8%) or FMI_{DXA} (23.2%). BMI observed any case of "obesity", but $\%FM_{DXA}$ (10.2%) and FMI_{DXA} (1.4%) indicated the lowest occurrences. Among men, "normal" was 66.7% (BMI), 34.8% ($\%FM_{DXA}$) and 34.8% (FMI_{DXA}). "Thinness" frequency cases were very low for BMI (1.5%), but were more than a third of the sample with $\%FM_{DXA}$ (37.9%) and FMI_{DXA} (34.8%). "Overweight" was 27.3% (BMI), 15.2% ($\%FM_{DXA}$), 21.2% (FMI_{DXA}), while "obesity", was the lowest observed frequency with 4.5% (BMI), 12.1% ($\%FM_{DXA}$) and 9.1% (FMI_{DXA}).

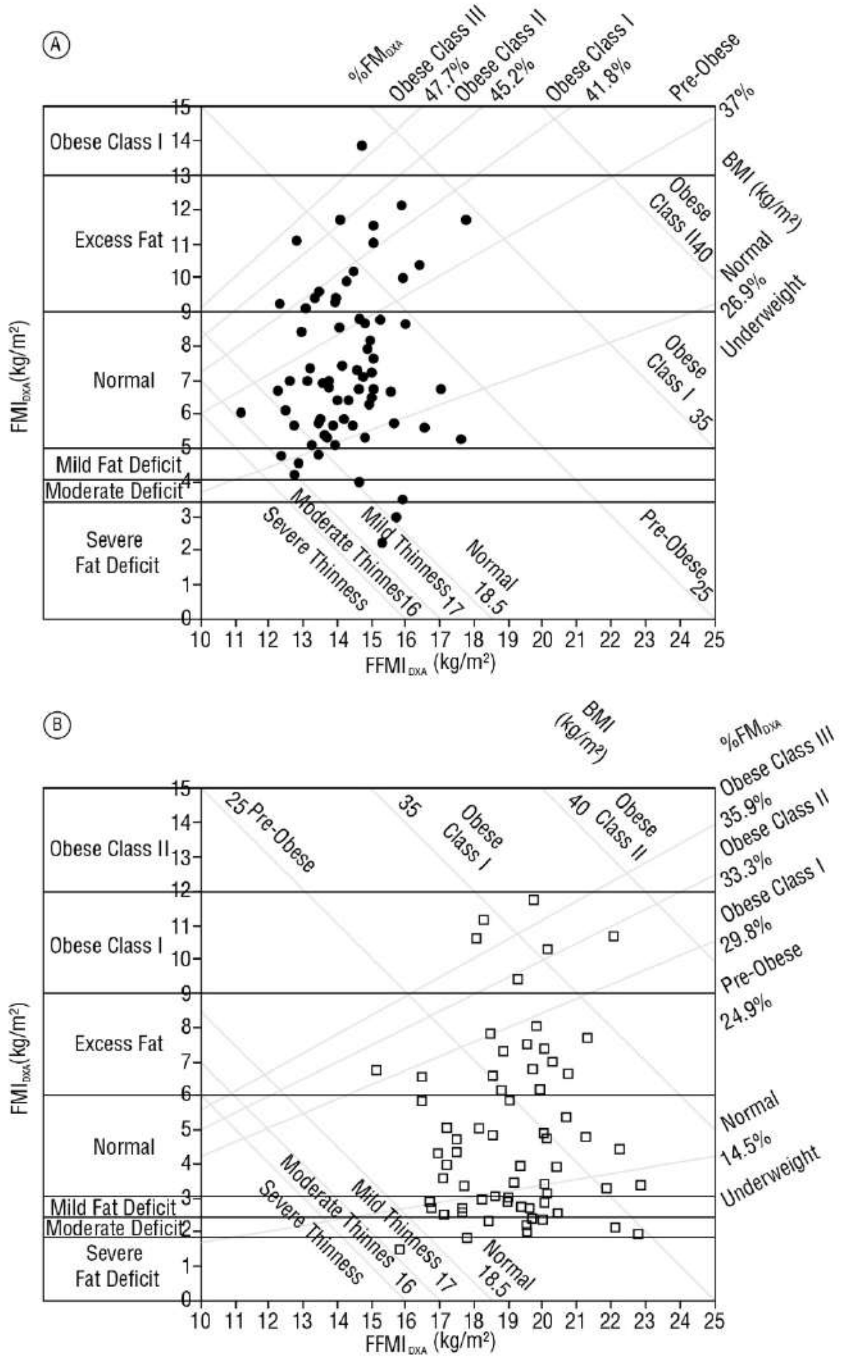

Figure 1. Relationship between BMI, %FMDXA, FMIDXA and FFMIDXA and the description of the nutritional status classification according to BMI, %FMDXA, FMIDXA for female (a) and male (b) young adults. BIA: electrical bioimpedance; BMI: body mass index[2]; DXA: dual energy X-ray absorptiometry; FMI: fat mass index[8]; FFMI: fat-free mass index; ST: skinfolds thickness; %FM: percentage of fat mass[20]

Figure 2 shows for each sex the agreement between the FMI measurement instruments (BIA, ST, and DXA). For females, FMI_{BIA} (-2.0 kg/m²) and FMI_{ST} (-1.9 kg/m²) did not show good agreement with FMI_{DXA}, indicating bias. The limits of agreement (±1.96 SD) between FMI_{DXA} and FMI_{BIA} were higher (2.0 and - 6.2 kg/m²) than FMI_{ST} (-0.0 and -3.8 kg/m²). BIA (r=0.94; p<0.001) and ST (r=0.449; p<0.001) present heteroscedasticity with the reference.

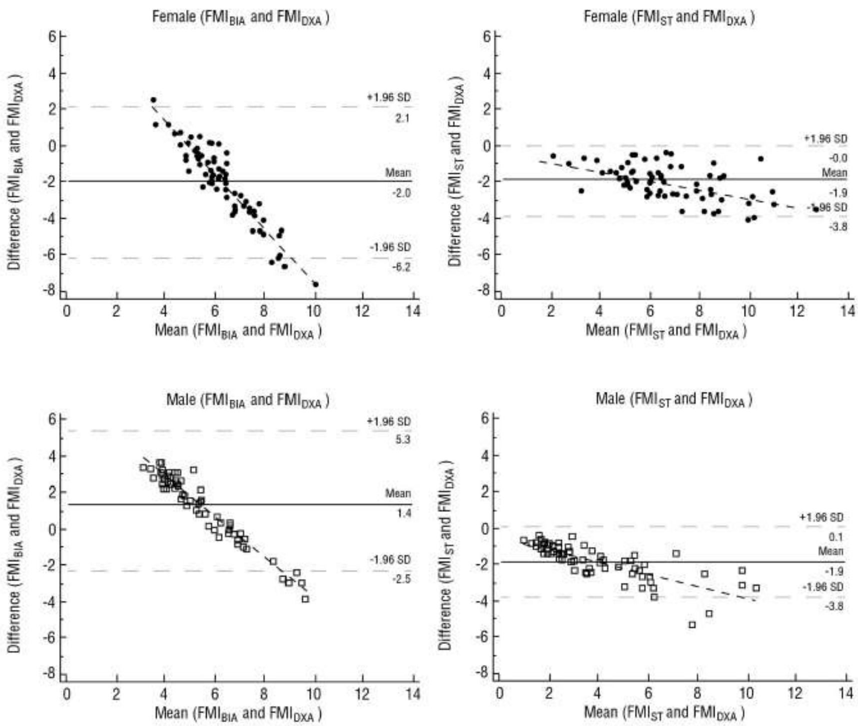

Figure 2. Analysis of agreement (Bland-Altman) between FMIBIA, and FMIST concerning FMIDXA for the female and male sexes. BIA: electrical bioimpedance; DXA: dual-energy X-ray absorptiometry; FMI: fat mass index; ST: skinfolds thickness.

For males, FMI_{BIA} overestimated FMI_{DXA} with a bias of 1.4 kg/m^2, while FMI_{ST} was underestimated by -1.9 kg/m^2. The limits of agreement (±1.96 SD) between FMI_{DXA} and FMI_{BIA} (5.3 and -2.5 kg/m^2) were higher than FMI_{ST} (-0.1 and -3.8 kg/m^2). There is heteroscedasticity for BIA (r=0.971; p<0.001) and ST (r=0.739; p<0.001), confirming the lack of agreement with the reference (DXA).

Tables 2 (female) and 3 (male) shows the NS classification comparison with the cutoff points of the FMI_{DXA} (NHANES)[8] and BIA/ST.

Table 2. Cross-tabulation of the nutritional status classifications according to FMI_{DXA} and FMI_{BIA}; FMI_{DXA} and FMI_{ST} for females.

	Severe fat deficit *n* (%)	Moderate fat deficit *n* (%)	Mild fat deficit *n* (%)	Normal *n* (%)	Excess fat *n* (%)	Total *n* (%)
FMI_{DXA}			**FMI_{BIA}**			
Severe fat deficit	-	-	3 (100%)	-	-	3 (100%)
Mild fat deficit	-	-	3 (60%)	2 (40%)	-	5 (100%)
Normal	-	-	12 (27.3%)	32 (72.7%)	-	44 (100%)
Excess fat	-	-	-	16 (100%)		
Obese Class I	-	-	-	1 (100%)		
FMI_{DXA}			**FMI_{ST}**			
Severe fat deficit	3 (100%)	-	-	-	-	3 (100%)
Mild fat deficit	5 (100%)	-	-	-	-	5 (100%)
Normal	-	7 (15.9%)	17 (38.6%)	20 (45.5%)	-	44 (100%)
Excess fat	-	-	-	14 (87.5%)	2 (12.5%)	16 (100%)
Obese Class I	-	-	-	-	1 (100%)	1 (100%)

Note. BIA: electrical bioimpedance; DXA: dual energy X-ray absorptiometry; FMI: fat mass index; FFMI: fat-free mass index; *n*: absolute frequency; ST: skinfolds thickness; %: relative frequency.Kappa Index (k)=0.033; p=0.607 for BIA; k=0.023; p=0.696 for ST.

Table 3. Cross-tabulation of the nutritional status classifications according to FMI_{DXA} and FMI_{BIA}; FMI_{DXA} and FMI_{ST} for males.

	Severe fat deficit *n* (%)	Moderate fat deficit *n* (%)	Mild fat deficit *n* (%)	Normal *n* (%)	Excess fat *n* (%)	Total *n* (%)
FMI_{DXA}			**FMI_{BIA}**			
Severe fat deficit	-	-	-	4 (100%)	-	4 (100%)
Moderate fat deficit	-	-	-	3 (100%)	-	3 (100%)
Mild fat déficit	-	-	-	14 (87.5%)	2 (12.5%)	16 (100%)
Normal	-	-	-	15 (62.2%)	8 (34.8%)	23 (100%)
Excess fat	-	-	-	-	14 (100%)	14 (100%)
Obese Class I	-	-	-	-	6 (100%)	6 (100%)
FMI_{DXA}			**FMI_{ST}**			
Severe fat deficit	4 (100%)	-	-	-	-	4 (100%)
Moderate fat deficit	3 (100%)	-	-	-	-	3 (100%)
Mild fat deficit	15 (93.8%)	1 (6.3%)	-	-	-	16 (100%)
Normal	6 (26.1%)	5 (21.7%)	5 (21.7%)	7(30.4%)	-	23 (100%)
Excess fat	-	-	-	13 (92.9%)	1 (7.1%)	14 (100%)
Obese Class I	-	-	-	2 (33.3%)	4 (66.7%)	6 (100%)

Note. BIA: electrical bioimpedance; DXA: dual energy X-ray absorptiometry; FMI: fat mass index; FFMI: fat-free mass index; *n*: absolute frequency; ST: skinfolds thickness; %: relative frequency. Kappa index (k)= 0.214; p = 0.001 for BIA; k = 0.002; p = 0.973 for ST.

For females, the coefficients of agreement between the NS classifications by FMI_{BIA} and FMI_{DXA} were "slight" (k=0.033; p=0.607), coinciding in 50.7% of the classifications. FMI_{BIA} did not classify cases of "severe deficit", "moderate deficit", "excess" of fat, or "obesity". The 17 women classified by FMI_{DXA} with "excess fat" (n=16) and "obesity" (n=1), were all considered "normal" by FMI_{BIA}. About 40% of those who had a "mild deficit" of fat (FMI_{DXA}) were also "normal" by FMI_{BIA}. The agreement between the classifications by FMI_{ST} and FMI_{DXA} was "slight" (k=0.023; p=0.696), coinciding with 36.2% of the classifications. FMI_{ST} did not discriminate against cases of "obesity" and agreed with FMI_{DXA} in only 12.5% of "excess fat" cases. There were also 87.5% of women with "excess fat" (FMI_{DXA}) classified as "normal" by FMI_{ST}. FMI_{ST} also classified more than half (55.5%) of women in "normal" NS (FMI_{DXA}) as "moderate fat deficit" (n=7) or "mild fat deficit" (n=17).

For males, there was a "fair" coefficient of agreement between the FMI_{BIA} and FMI_{DXA} NS classifications (k=0.214; p=0.001), coinciding in 43.9% of classifications. FMI_{BIA} classified men in only two categories of the NS: "normal" and "excess fat". About 91% of the cases classified by FMI_{DXA} with some fat deficits (n=21) were classified as "normal" by the FMI_{BIA}. About 12% of the "mild fat deficit" cases with FMI_{DXA} were classified as "excess fat" by FMI_{BIA}. "Obesity" cases (n=6) by FMI_{DXA} were classified as "excess fat" with FMI_{BIA}. There was a "poor" agreement between the FMI_{DXA} and FMI_{ST} NS classifications (k=0.002; p=0.973), coinciding in 18.8% of classifications. FMI_{ST} classifies 69.5% of the normal cases (FMI_{DXA}), with some fat deficit; FMI_{ST} still classified 93% of the "excess fat" by FMI_{DXA} as "normal" cases. In addition, of the total cases of "obesity class I" by FMI_{DXA}, 33.3% were "normal" and 66.7% were "excess fat" by FMI_{ST}.

DISCUSSION

The main finding of this study was not confirming our hypothesis, BIA/ST could not be used to determine the NS according to the referential (NHANES)[7] established by DXA. Since ST/BIA are clinically available instruments we expected that the FMI differences with DXA would not invalidate their interchange use, as it deals with classification within a given interval. There was also no agreement (Bland Altman) between the instruments in determining the FMI absolute values. For FMI absolute values, BIA agreed less with the reference (DXA) than ST, while for NS classification ST became to agree less with the reference (DXA) than BIA. This was because BIA did not classify cases of extreme fat deficits, while ST and DXA did. Precisely in the fat deficit cases, the cut-off points range smaller[7], being more susceptible to exhibit classification divergences between ST and DXA. In other populations was also observed the lack of agreement between FMI_{BIA} and FMI_{ST}[22,23]. Despite the index used relativizing FM by Ht^2 the differences remain significant suggesting that instrument choice matters. In addition to using different methodologies, an explanation is that instruments indirectly estimate FM based upon different conceptual assumptions and positions in the five-level model of body composition established by Wang et al.[24]

When DXA, BIA, and ST measure FMI, the values are not the same because they have different baseline assumptions. DXA was used to determine NHANES's NS threshold, corresponding to level II (molecular) in the five-level model. DXA also indirectly estimates FM with acceptable precision by the mass attenuation coefficient (R) of the double X-ray beams of the atomic elements that compose the FM. Each atomic element has a characteristic mass R-value. The elements with low atomic numbers (hydrogen and carbon) have a lower R, while the elements with a high atomic number (calcium and phosphorus) have a higher R. FM, which contains more carbon, has less R-value than the FFM[11]. BIA, in turn, is based on electrical conductivity, not corresponding in a particular position in the five-level model[24], without consensus about classification, being found in levels II[25], III (cellular)[26] or V (whole-body)[27]. BIA estimates FM by the inverse relationship between impedance (Z) and the volume of TBW through which the alternating electric current flows. In addition, BIA estimates FFM through TBW, which hydration influences much more than DXA/ST[11]. Men have a higher rate of sweating and are more prone to dehydration[28], which possibly explains the positive biases concerning FMI_{BIA} (and the negative of its complement, $FFMI_{BIA}$)[23]. The ST corresponds to level V[24] based on the body density derived from BM and total body volume, considering constant values for each component (FM: 0.900 g/cm^3; FFM: 1.100 g/cm^3). Therefore, in a 2-C approach based on the relationship between subcutaneous fat and total FM[11], the ST regression equations to determine body density allow %FM calculation.

Indeed, beyond the epidemiological context, the BMI is widely used to categorize NS and brings a conceptual confusion. BMI does not assess the FM nor its distribution across the body. For instance, "normal" NS classified with BMI is with FMI "obese" in 4% of cases[3]. In the "overweight" BMI category, FMI classified 65.5% of men and 71.3% of women as "obese"[3]. Therefore, BMI and FMI cannot be used interchangeably.

One of them involves the original population to determine BIA and ST equations since these equations are originally from other countries.

Our convenience sample limits the generalization of our findings, mainly due to the lack of ethnic representativeness. Even considering the high Brazilian miscegenation, it is worth mentioning that in the NHANES study there were no ethnic differences in the NS classification between Africans, Caucasians, and Hispanics[7]. Thus, the ethnic difference does not seem to influence the results since the indexes deal with intrapersonal relationships of body measures. Even though, our intention was exclusively inferential in the comparison between instruments, without an additional purpose for populating the findings.

We used DXA as a comparative reference instrument, just like NHANES. Another strong point involves the use of the adapted Hattori Chart[20]. We allow the NS categories visualization of each indicator at the same time, identifying the divergences between them. In addition, the demarcation lines of the NS of each indicator allow comparing the NS classifications on a case-by-case basis.

In the field of application of physical and aesthetic performance, the simultaneous use of BMI with FMI can detect skeletal muscle mass loss with the preservation of FM. This can result in serious impacts on the various performances, alerting to the need for planned interventions to adjust the Wt[29]. In the clinical field, there are cut-off points for FMI to diagnose metabolic syndrome: 6.97 kg/m^2 for men and 11.86 km/m^2 for women[4]. The sensitivity of FMI, to detect changes in body composition was evaluated during Wt control program for obese children[30], The FMI compared to %FM and BMI showed greater sensitivity for revealing adiposity reduction in a shorter period. BMI detects rates of reduction of only 5% in adiposity in 33.3% of children, but the figures reached 63.3% using the %FM and up to 70.0% when the losses were based on the FMI. When comparing the meantime (days) to detect differences in adiposity, the result was similar between FMI (71) and BMI (70), but both were significantly shorter than the required for %FM (88)[30].

CONCLUSION

Different forms of NS classification according to the FMI between the instruments (DXA, BIA, and ST) do not guarantee reliable agreement to use those interchangeably. We recommend in clinical practice or research use the NHANES NS classification proposal exclusively by DXA if body indexes are determined. The NS thresholds must be specifically determined for each sex and instrument, respecting population characteristics. Thus, the challenge remains for future NS classification proposals using clinically viable instruments (ST and BIA) with more detailed categories, capable of differentiating degrees of "obesity" or "thinness". The lack of agreement between the instruments confirms that the principles are not the same for determining the absolute values of FMI, indicating that the instrument used in each situation does matter, even though there is some interdependence between the instruments capable of distinguishing FM from FFM.

COMPLIANCE WITH ETHICAL STANDARDS

Funding

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - 33002029053P1.

Ethical approval

Ethical approval was obtained from the Human Research Ethics Committee of the School of Physical Education and Sport of Ribeirao Preto at the University of Sao Paulo, and the protocol was written in accordance with the standards established by the Declaration of Helsinki.

Conflict of interest statement

The authors have no conflict of interests to declare.

Author Contributions

Conception and design of the experiment: FGB, DRLM. Carrying out the experiments: PPA, TCA, ACRV, APS. Data analysis FGB, PPA, DRLM. Contribution with reagents/research materials/analysis tools: SA, JM, DRLM. Writing of the article: FGB, PPA, TCA, ACRV, MFTJ, SA, JM. All authors read and approved the final version of the manuscript.

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