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Application of body mass index adjusted for fat mass (BMIfat) obtained by bioelectrical impedance in adults

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Abstract

Introduction: **Body mass index (BMI) has been one of the methods most frequently used for diagnose obesity, but it isn't consider body composition.**

Objective: **This study intends to apply one new adiposity index, the BMI adjusted for fat mass (BMIfat) developed by Mialich et al. (2011), in a adult Brazilian sample.**

Methods: **A cross-sectional study with 501 individuals of both genders (366 women, 135 men) aged 17 to 38 years and mean age was 20.4 ± 2.8 years, mean weight 63.0 ± 13.5 kg, mean height 166.9 ± 9.0 cm, and BMI 22.4 ± 3.4 kg/m².**

Results and discussion: **High and satisfactory R2 values were obtained, i.e., 91.1%, 91.9% and 88.8% for the sample as a whole and for men and women, respectively. Considering this BMIfat were developed new ranges, as follows: 1.35 to 1.65 (nutritional risk for malnutrition), > 1.65 and ≤ 2.0 (normal weight) and > 2.0 (obesity). The BMIfat had a more accurate capacity of detecting obese individuals (0.980. 0.993, 0.974) considering the sample as a whole and women and men, respectively, compared to the traditional BMI (0.932, 0.956, 0.95). Were also defined new cut-off points for the traditional BMI for the classification of obesity, i.e.: 25.24 kg/m² and 28.38 kg/m² for men and women, respectively.**

Conclusion: **The BMIfat was applied for the present population and can be adopted in clinical practice. Further studies are needed to determine its application to different ethnic groups and to compare this index to others previously described in the scientific literature.**

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Key words: *Body composition. Body mass index. Bioelectrical impedance. Body fat.*

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APLICACIÓN DEL ÍNDICE DE MASA CORPORAL PARA AJUSTAR LA MASA DE GRASA OBTENIDO POR IMPEDANCIA BIOELÉCTRICA EN ADULTOS

Resumen

Introducción: **El índice de masa corporal (IMC) es uno de los métodos que se utilizan con mayor frecuencia para diagnosticar la obesidad, pero ese no considera la composición corporal.**

Objetivo: **Este estudio objetivó aplicar un nuevo índice de adiposidad, el IMC ajustado por la masa de grasa (BMIfat) desarrollado por Mialich et al . (2011), en una población adulta brasileña.**

Métodos: **Estudio transversal con 501 individuos de ambos sexos (366 mujeres y 135 hombres) entre 17 y 38 años, edad media de 20,4 ± 2,8 años, con una media de peso de 63,0 ± 13,5 kg, con una media de altura 166,9 ± 9,0 cm, y IMC 22,4 ± 3,4 kg/m².**

Resultados y discusión: **Se obtuvieron altos y satisfactorios valores de correlación (R2): 91,1% , 91,9% y 88,8% para la muestra en su conjunto y para los hombres y mujeres, respectivamente. Teniendo en cuenta este BMIfat se han desarrollado nuevas gamas, de la siguiente manera: 1,35-1,65 (riesgo nutricional para la malnutrición), > 1,65 y ≤ 2,0 (peso normal) y > 2,0 (obesidad). El BMIfat tiene una capacidad más precisa de detectar individuos obesos (0,980; 0,993; 0.974; considerando la muestra en su conjunto y las mujeres y los hombres, respectivamente), en comparación con el índice de masa corporal tradicional (0,932; 0,956; 0,95). También fueron definidos nuevos puntos de corte para el IMC tradicional para la clasificación de la obesidad: 25,24 kg/m² y 28,38 kg/m² para los hombres y mujeres, respectivamente.**

Conclusión: **El BMIfat se aplicó para la población actual y puede ser adoptado en la práctica clínica. Se necesitan más estudios para determinar su aplicación a los diferentes grupos étnicos y para comparar ese índice con otros descritos previamente en la literatura científica.**

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Palabras clave: *Composición corporal. Índice de masa corporal. Impedancia bioeléctrica. Grasa corporal.*

Introduction

According to the World Health Organization (WHO), obesity is defined as excess adipose tissue.[1] Today obesity can be considered to be the most important nutritional disorder in developed countries; its incidence is believed to reach 10% of the population of these countries[2] and more than one third of the North American population is believed to be above the desirable weight. Thus, obesity is being considered to be a worldwide epidemic, present both in developed and developing countries.[2]

Brazil occupies 77th position in the WHO ranking; in 2010 the Health Ministry and the Brazilian Institute of Geography and Statistics (IBGE) published two large surveys of excess weight and obesity data in Brazil: the Vigilance of Risk Factors and Protection against Chronic Diseases by Telephone Interview (VIGITEL Brazil 2009), and the Survey of Family Budgets 2008-2009 (POF). The first survey revealed a frequency of excess weight of 46.6%, with a higher rate among men (51.0%) than among women (42.3%). This tendency was confirmed by the POF, which demonstrated that excess weight almost tripled among men from 18.5% in 1974-75 to 50.1% in 2008-09, and increased from 28.7% to 48% among women.

The index universally accepted for the classification of obesity is the body mass index (BMI) proposed by Quetelet in 1835, which is expressed as body weight in kg divided by height squared in meters (weight/height^2). In 1997, the WHO adopted this index as a reference measurement of obesity, with overweight and obesity being defined as a BMI range of 25.0-29.9 kg/m^2 and a BMI above 30.0 kg/m^2, respectively. Since then, these cut-off points have been used as standards in different populations and different ethnic groups, based on the assumption that these different ethnic groups have similar risks of mortality/morbidity. However, recent studies[3,4,5] have shown that there still is controversy about the best BMI for the classification of obesity in different populations.

In view of these problems regarding obesity, there is a pressing need to propose a refinement of the BMI by validating a new BMI adjusted for fat mass [(3 Weight + 4 Fat Mass) Height] previously developed by Mialich et al. (2011).[3] There is also the need to develop new classification ranges for the adoption of this index in clinical practice.

Methods

Subjects

The study was conducted on healthy individuals of both genders, i.e., adolescents aged 17 years to 19 years, 11 months and 29 days and adults aged 20 years or older[6] enrolled in undergraduate courses of the University of Sao Paulo (USP). The courses were chosen at random and by convenience and all students of one class were invited to participate.

The students gave written informed consent to participate in the study (protocol nº 1955/2010) and all the procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation. All the individuals were then submitted to measurement of weight and height and evaluation of body composition by bioelectrical impedance.

Exclusion criteria were: inability to walk, amputation, presence of metal objects in the body, difficulty in making the measurements, or interference with the results of bioelectrical impedance. The participation of the students was voluntary and all individuals were evaluated only once during the study by a group of trained examiners.

Anthropometric evaluation

Body weight (kg) was measured with an electronic scale (BC-558 Ironman Segmental Body Composition Monitor, Tanita Corp., Tokyo, Japan) with a maximum capacity of 150 kg and precision of 0.01 kg. Weight was measured after at least 5 hours of fasting, followed by bladder emptying, with the individuals wearing light clothing and no shoes. Height was measured with the aid of a wood bracket along a plastic tape fixed to a wall with no baseboard, with the subject standing up straight, barefoot and with head and neck aligned. Height (m) was measured twice with a maximum variation of 0.5 cm being permitted between measurements, and the mean of the two values was calculated.[7] BMI was calculated as weight (kg) divided by height (m) squared (kg/m^2). Criteria used to define overweight were the ones of the World Health Organization (WHO).[1] which considers obesity when BMI ≥ 30 kg/m^2.

Evaluation of body composition

Percentage of body fat mass was obtained by Tetrapolar Bioelectrical Impedance Analysis (BIA) system (BC-558 Ironman Segmental Body Composition Monitor, Tokyo, Japan). BIA measurements were carried out at 50 kHz with a 0.8 mA since wave constant current under standard conditions. Detailed instructions about electrode placements according to the manufacturer's manual were also provided.

For this exam, the individuals wore light clothing and no socks, with care taken to insure that their heels were correctly aligned with the electrodes of the measuring platform. The following requirements had to be fulfilled: fasting for at least 5 hours, no vigorous physical activity in the last 12 hours, wearing light clothing, urinating 30 minutes before the beginning of the exam, and abstaining from alcoholic or caffeinecontaining beverages for 12 hours before the exam. During the exam, the individuals held with their hands retractable levers with electrodes that functioned jointly with the foot electrodes, forming a 90º C angle between the base of the electrode and the rod connecting it to the equipment. After this measurement, which lasted approximately 30 seconds, the screen automatically presented the final result of the evaluation of body composition.

The new adiposity index (BMIfat) was calculated using the equation suggested by Mialich and colleagues (BMIfat) and weight in kg, fat mass in % and height in cm.[3]

Statistical analysis

For the analyses of the new index corrected for fat mass, regression models were adjusted, having the "new adjusted BMI" as the independent variable and the "traditional BMI" as the dependent variable, with the coefficient of determination (R2) being used as a measure of the predictive capacity of the "new adjusted BMI" compared to the "traditional BMI".

For the elaboration of the ranges of nutritional status classification for this new adjusted BMI so that it could be adopted in clinical practice we used the classification ranges of the traditional BMI associated with cut-off points for body fat of 25% and 35% for men and women, respectively.[1]

Considering the diagnostic performance of this BMIfat compared to the traditional BMI, it was calculated sensitivity, specificity, predictive values with their respective 95% and ROC curves (Receiver Operating Characteristic) for detecting areas under the curve, considering both BMI traditional as BMIfat for all individuals and separate gender. Simple linear regression was used for the definition of the new cut-off points of the BMI for the classification of obesity in this population. The Student was used to compare the means and analysis of variance (ANOVA) was used for the analysis of three means or more, with the level of significance set at $p < 0.05$ for both tests. All this analysis used the software SAS version 9.

Results

The sample consisted of 27.0% men and 73.0% women, 84.7% of them being white, 10.1% mulatto, 3.8% oriental, and 1.4% black. Mean age was 20.4 ± 2.8 years for the sample as a whole, 20.8 ± 3.2 years for men, and 20.3 ± 2.7 years for women, with no significant difference between groups.

The values of the variables weight, height and BMI were significantly higher for men (71.7 ± 18.5 kg, 169.6 ± 8.4 cm and 24.4 ± 3.8 kg/m2, respectively) than for women (64.6 ± 16.0 kg, 157.2 ± 5.8 cm and 21.7 ± 3.0 kg/m^2, respectively).

Regarding the remaining body composition data, men had significantly higher values than women for fat-free mass (60.0 ± 7.7 kg *versus* 39.8 ± 3.8 kg) and total body water (59.9 ± 5.3 % *versus* 54.3 ± 4.4%), whereas fat mass was greater in women (26.6 ± 6.2% versus 17.0 ± 6.2%). There was no statistically significant difference with respect to age among both gender (20.8 ± 3.2 years versus 20.3 ± 2.7 years for men and women, respectively) (table I).

The individuals studied were enrolled in the following courses: Medicine (n = 62), Nutrition (n = 98), Speech Therapy (n = 44), Physiotherapy (n = 75), Occupational Therapy (n = 27), Biomedical Informatics (n = 43), Physical Education (n = 59), and Nursing (n = 93). Most of them were single, were non-smokers, and were not employed, but were taking alcoholic drinks.

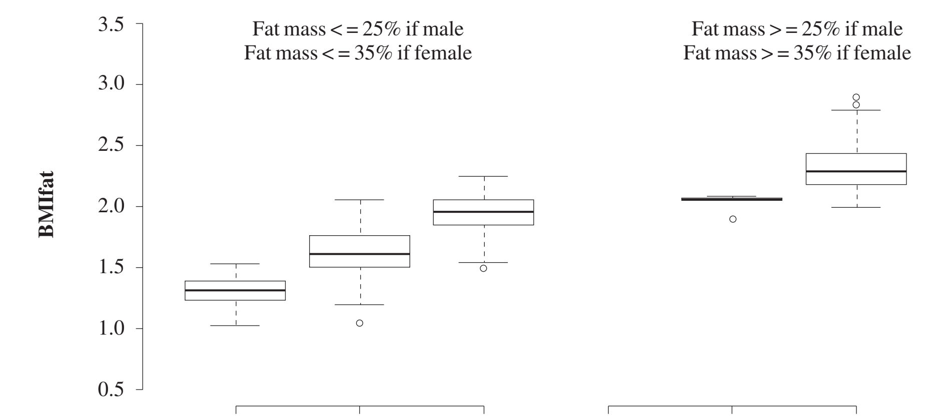
Linear regression models were used for analysis of the BMI adjusted for fat mass and the coefficient of determination (R2) was used as a measurement of the predictive capacity of the "adjusted BMI" compared to the "traditional BMI". When the sample was considered as a whole, the R2 was 91.1%, and when the individuals were divided according to gender, the R2 was 91.9% and 88.8% for men and women, respectively.

One of the secondary objectives of the present study was to develop ranges of classification for this new index so that it could be used in clinical practice. In this respect, the sample data were distributed according to the ranges of the traditional BMI defined by the WHO[1] and according to the new values obtained after calculating the BMI adjusted for fat mass (fig. 1). It can be seen

Table I
Description of anthropometric and body composition of all subjects and separated by gender, male and female

	All (n = 501)	*Male (n = 135)*	*Female (n = 366)*	*p value**
Age (years)	20,4 ± 2,8	20,8 ± 3,2	20,3 ± 2,7	0,0813
Weight (kg)	63,0 ± 13,5	76,9 ± 13,6	57,8 ± 9,2	< 0,0001
Height (m)	166,9 ± 9,0	177,3 ± 6,7	163,1 ± 6,3	< 0,0001
BMI (kg/m^2)	22,4 ± 3,4	24,4 ± 3,8	21,7 ± 3,0	< 0,0001
FFM (kg)	45,3 ± 10,3	60,0 ± 7,7	39,8 ± 3,8	< 0,0001
FM (%)	24,0 ± 7,5	17,0 ± 6,2	26,6 ± 6,2	< 0,0001
TBW (%)	55,8 ± 5,2	59,9 ± 5,3	54,3 ± 4,4	< 0,0001

*Comparisons the means between the genders with Student t-test and statistical significance if $p < 0.05$.
BMI: Body mass fat; FFM: Fat-free mass; FM: Fat mass; TBW: Total body water.



BMI (kg/m²)	< 18.5	18.5-24.9	> 24.9	< 18.5	18.5-24.9	> 24.9
n	50	342	60	0	7	42
Mean	1.32	1.64	1.94		2.04	2.33
SD	0.12	0.18	0.17		0.07	0.22

Fig. 1.—Subject distribution by gender according to the classification ranges for the traditional BMI, considering the corresponding values of adjusted BMI (BMIfat) corresponding to cut-off points for fat mass of 35% and 25% for women and men, respectively.

that the suggested ranges of the adjusted BMI corresponding to the traditional BMI considering the sample as a whole would be: 1.35 to 1.65 (risk for malnutrition), > 1.65 and ≤ 2.0 (normal weight) and > 2.0 (obesity).

Considering the cut-off points for fat mass for the classification of obesity proposed by the WHO, i.e., 25% and 35% for men and women, respectively, it is possible to compare the capacity of the traditional BMI and the capacity of the new adjusted BMI to detect obesity in the sample evaluated. It can be seen that the area under the curve for the adjusted BMI (0.980, 0.993, 0.974) was greater than that of the traditional BMI (0.932, 0.956, 0.95) for the classification of obesity considering the sample as a whole and divided into men and women, respectively (figs. 2 and 3).

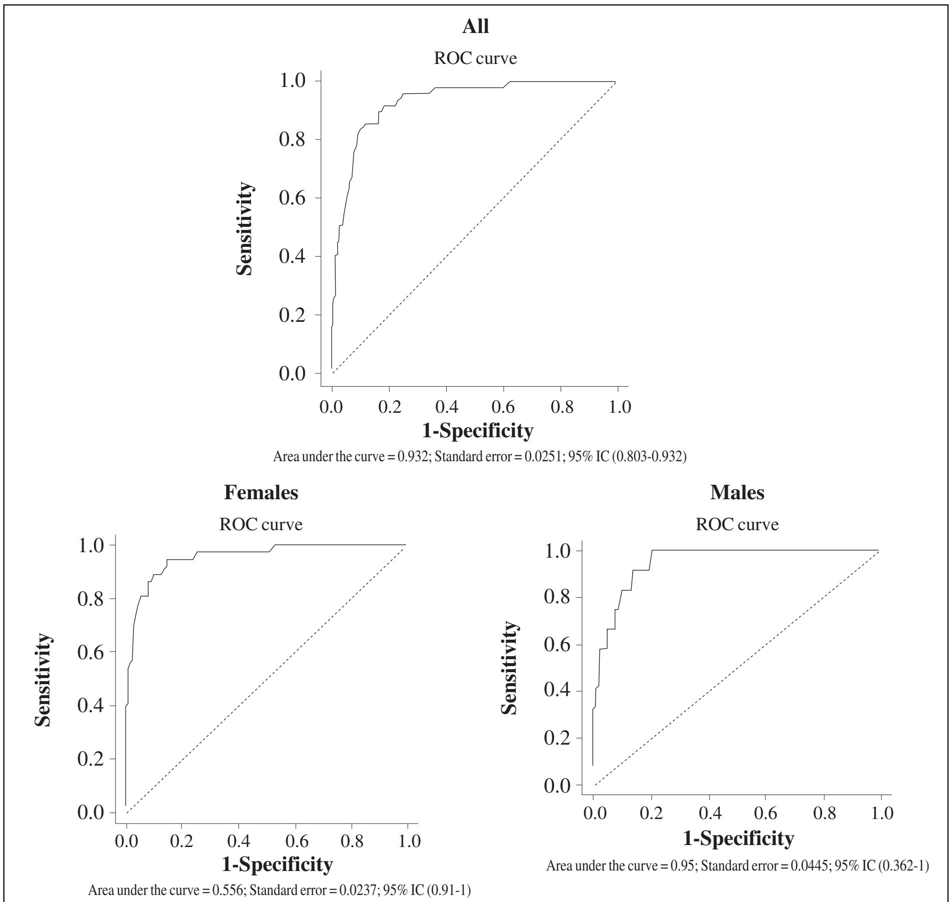


Fig. 2.—Subject distribution according to the cut-off points for body fat (25% for men and 35% for women) and traditional BMI values followed by their respective ROC curves, divided into the study group as a whole, and women and men, respectively.

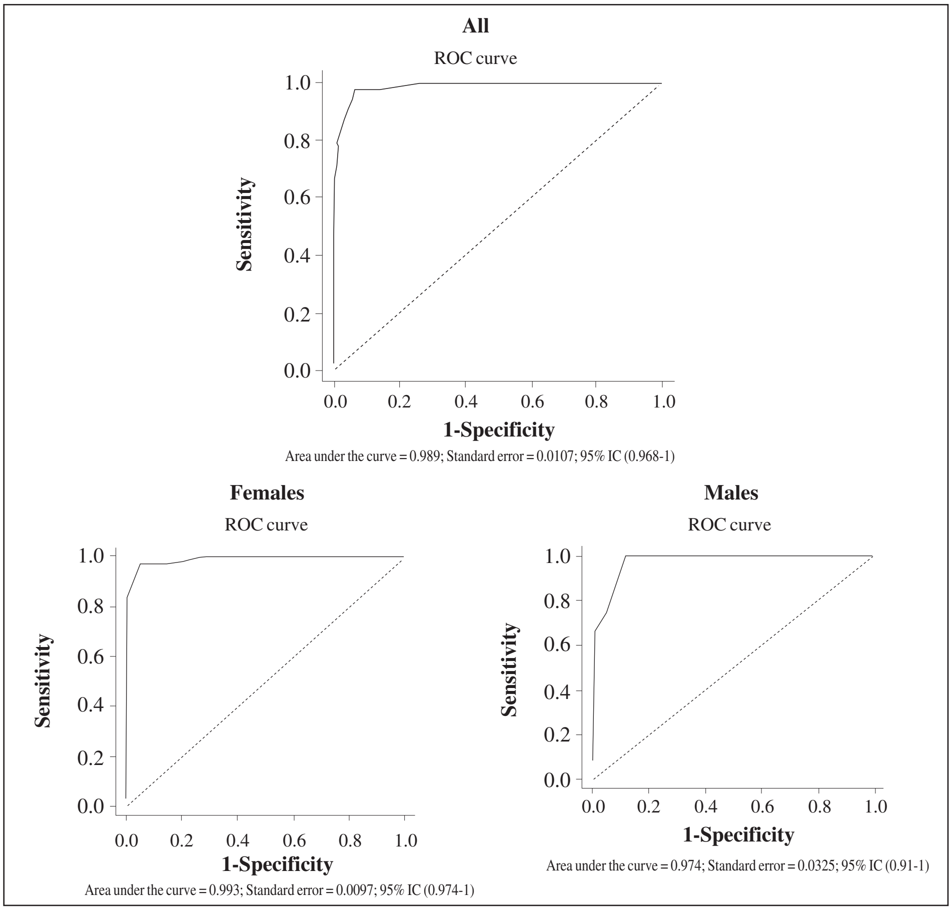


Fig. 3.—Subject distribution according to the cut-off points for body fat (25% for men and 35% for women) and BMI values adjusted (BMIfat) according to their respective ROC curves, divided into the study group as a whole, and women and men, respectively.

We also intended to propose new cut-off points for the BMI for the correct classification of nutritional status in the Brazilian population. For this purpose, we performed regression analysis and obtained new values of the traditional BMI for the detection of obesity in this sample, which were: 25.24 kg/m^2 (considering body fat = 35%) and 28.38 kg/m^2 (considering body fat = 25%) for women and men, respectively.

When the same analysis was carried out, but now considering the new adjusted BMI, the following new cut-off points were obtained: 1.85 (for body fat = 30%) and 2.1 (for body fat = 35%), both for women, and 1.8 (for body fat = 20%) and 2.08 (for body fat = 25%), both for men, as illustrated in Figure 4. It can be seen that the cut-off points for the BMI adjusted for the classification of overweight and obesity were closely similar for the two genders, underscoring one of the major advantages of this index, i.e., its uniform applicability to both genders, as illustrated in figure 4.

Discussion

The present study, conducted on a sample of the adult Brazilian population, demonstrated a limited diagnostic performance of the traditional BMI for the correct identification of individuals with excess body fat and proposed the adoption of a BMI adjusted for fat mass [(3 Weight + 4 Fat Mass)/Height], which was applied for the sample under study as described earlier. However, the authors emphasize that new studies with randomized samples representative of the Brazilian population are still necessary.

Another objective of the present study in addition to application was to develop ranges of classification of the new index so that it could be applied to routine clinical practice. On this basis, we opted to describe ranges that would consider the sample as a whole since the major focus of the study was to keep the new index simple so that it could be applied to all individuals without any additional variable that would involve dividing the equation between men and women. Thus, in order to facilitate the use and interpretation of this adjusted index in clinical practice, we opted for the same adjusted BMI ranges for both genders (1.35 to 1.65, > 1.65 and ≤ 2.0, and > 2.0) that would correspond to those of the traditional BMI. At this time, we should point out the limitation of the present study due to the failure to adopt a gold standard technique for the comparison of the index, as done by Bergman et al. (2011), who opted for DXA for the validation of the Body Adiposity Index (BAI).[8]

In addition, the present study also proposes new cut-off points for the classification of obesity considering

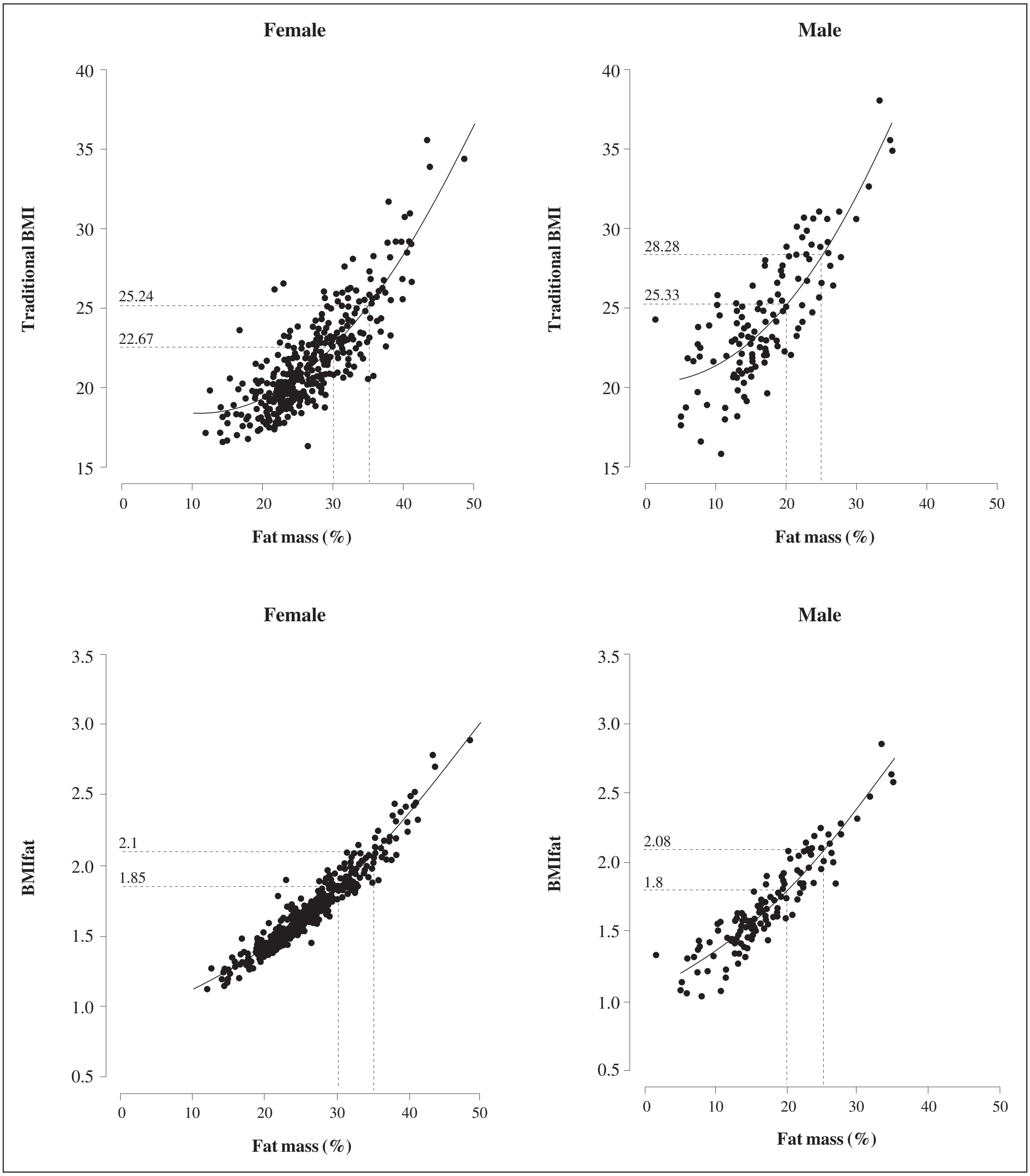


Fig. 4.—Cut-off point of the traditional BMI and the BMIfat for the detection of obesity in men and women of the sample studied, considering percentages of body fat for the classification of overweight and obesity of 20% and 25% and 30% and 35% for men and women, respectively.

35% body fat for women and 25% for men, corresponding to 25.24 kg/m2 and 28.38 kg/m^2 for men and women, respectively.

Other studies have also been published in the literature to propose and discuss new cut-off points for the BMI for the classification of obesity in different ethnic groups, as shown by the comparative data presented in table II.[3-4,9-20]

Among the limitations of this study, the authors acknowledge that the sample used was a sample of convenience, and this has limited applicability, especially for being composed of young people who have narrow bands for age and body composition. Moreover, they know that the method used to assess body composition, BIA, is not a method of reference. However, many studies have shown a high correlation

Table II
Comparative summary of studies proposing new cut-off points of BMI for the classification of overweight/obesity in men and women

Reference	*Country*	*n*	*BMI cut off points - Men*	*BMI cut off points - Women*
Deurenberg-Yap et al. (2000)[9]	Singapore	291	26.0 to 27.0 kg/m^2	26.0 to 27.0 kg/m^2
Frankenfield et al. (2001)[10]	USA	141	22.6 kg/m^2	20.1 kg/m^2
Ko et al. (2001)[11]	China	5153	23.0 – 26.0 kg/m^2	23.0 – 26.0 kg/m^2
Craig et al. (2001)[12]	Australia	393	26.9 kg/m^2	24.5 kg/m^2
Dudeja et al. (2001)[13]	India	123	21.5 kg/m^2	19.0 kg/m^2
Oh et al. (2004)[14]	Korea	773.915	25.0 kg/m^2	25.0 kg/m^2
Kagawa et al. (2006)[15]	Japan	139	–	23.0 kg/m^2
Bozkirli et al. (2007)[16]	Turkey	909	28.24 kg/m^2	28.02 kg/m^2
Romero-Corral et al. (2008)[17]	USA	13601	25.8 kg/m^2	25.5 kg/m^2
Laughton et al. (2009)[18]	Canada	77	22.1 kg/m^2	22.1 kg/m^2
Mialich et al. (2011)[3]	Brazil	200	21.84 – 26.11 kg/m^2	22.0 – 25.3 kg/m^2
Gupta e Kapoor (2012)[4]	India	578	22.9 – 28.8 kg/ m^2	22.9 – 28.8 kg/ m^2
Gómez-Ambrosi et al. (2012)[19]	Spain	6123	29.0 kg/m^2	27.0 kg/m^2
Laurson, Eisenmann and Welk (2011)[20]	USA	8268	Percentil 83	Percentil 80
Present study	Brazil	501	28.38 kg/ m^2	25.24 kg/m^2

with data obtained by BIA and gold standard techniques such as DXA.[21]

The BIA has been adopted as an attempt to let the new index easy to be applied to the extent that you need cheap equipment, easy to use, portable and available in most institutions. Thus, associating other variables such as weight and height to the fat mass data obtained by BIA provides a refinement of the assessment of body composition.

Conclusion

Thus, even though the BMI is a measurement internationally adopted for the classification of nutritional status, it does not evaluate body composition since it does not differentiate between fat mass and fat-free mass, possibly leading to incorrect diagnoses and therefore erroneous clinical interventions. The proposed adjusted BMI (BMIfat) was applied for the present sample and showed diagnostic superiority for the classification of obesity compared to the traditional BMI. New BMI ranges adjusted for the classification of obesity in the adult Brazilian population were also proposed, permitting the inclusion of a larger number of individuals and consequently an earlier clinical intervention. Further studies are needed to determine the application of this BMIfat to different randomized ethnic groups and to compare its diagnostic performance to that of other indices previously described in the scientific literature.

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