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Body fat assessment by bioelectrical impedance and its correlation with anthropometric indicators

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Abstract

Introduction: **Since the excess of body fat is associated with higher morbid-mortality rates (mainly in adults), precise, reliable, cost-effective, and broadly applicable methods are necessary for its assessment in population-based studies and in clinical practice.**

Objective: **To evaluate the correlation between body fat estimated either by bioelectrical impedance or by the sum of skinfold thicknesses and anthropometric indicators of fat distribution.**

Methods: **A cross-sectional study was conducted enrolled 348 undergraduate students (median 21 years), from the Federal University of Pernambuco, Northeast Brazil. Results: 262 of the subjects were women. Mean body fat assessed by bioelectrical impedance was 22.3 ± 6.2% in women and 15.2 ± 4.2% in men. Body fat obtained by the sum of skinfold thicknesses was similar to that assessed by bioelectrical impedance only in men. A strong correlation was observed between body fat assessed by bioelectrical impedance and that assessed by the sum of the skinfold thicknesses, waist circumference and waist-to-height ratio. Regarding the conicity index, there was a moderate correlation for men and a weak correlation for women.**

Conclusions: **The sum of skinfold thicknesses surrogate of body fat percentage and can be used to assess body fat when BIA is not available in the field. Additional information about central fat distribution can be supply by measuring the waist circumference or waist-to-height ratio.**

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Key words: *Body fat. Bioelectrical impedance. Skinfold thicknesses. Waist circumference. Wais-to-height ratio.*

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EVALUACIÓN DE LA GRASA CORPORAL POR IMPEDANCIA BIOELÉCTRICA Y SU CORRELACIÓN CON INDICADORES ANTROPOMÉTRICOS

Resumen

Introducción: **Desde que el exceso de grasa corporal se asocia con mayores tasas de morbi-mortalidad (sobre todo en los adultos), los métodos precisos y fiables, rentables, y aplicables en términos generales son necesarios para su evaluación en estudios basados en población y en la práctica clínica.**

Objetivo: **Evaluar la correlación entre la grasa corporal estimada, ya sea por impedancia bioeléctrica o por la suma de pliegues cutáneos y los indicadores antropométricos de la distribución de la grasa.**

Métodos: **Un estudio transversal se realizó con 348 estudiantes, con una edad promedio de 21 años, de la Universidad Federal de Pernambuco, nordeste de Brasil. La grasa corporal se evaluó mediante impedancia bioeléctrica y la suma de pliegues cutáneos. Circunferencia de la cintura, la relación cintura-altura y el índice de conicidad fueron utilizados como indicadores centrales de distribución de grasa**

Resultados: **262 de los sujetos eran mujeres. Media de la grasa corporal por impedancia bioeléctrica evaluados fue de 22,3 ± 6,2% en mujeres y 15,2 ± 4,2% en los hombres. Grasa corporal obtenida mediante la suma de pliegues cutáneos fue similar a la evaluada por impedancia bioeléctrica sólo en los hombres. Una fuerte correlación se observó entre la grasa corporal evaluada por impedancia bioeléctrica y espesores de los evaluados por la suma de los pliegues cutáneos, circunferencia de la cintura y relación cintura-altura. En cuanto al índice de conicidad, se observó una correlación moderada para los hombres y una correlación débil para las mujeres.**

Conclusiones: **La suma de pliegues cutáneos se puede utilizar para evaluar la grasa corporal en la ausencia de la impedancia bioeléctrica. Información adicional sobre la distribución de la grasa central puede ser la oferta mediante la medición del circunferencia de la cintura o la relación cintura-altura.**

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Palabras clave: *Grasa corporal. Impedancia bioeléctrica. Pliegues cutáneos. Circunferencia de la cintura. Relación cintura-altura.*

List of abreviations

BMI: Body mass index.
BIA: Bioelectrical impedance.
WC: Waist circumference.
WHtR: Waist-to-height ratio.
CI: Conicity index.
FatBIA: Body fat assessed by bioelectrical impedance.
UFPE: Federal University of Pernambuco.
WHO: World Health Organization.
DXA: Dual energy absorptiometry.

Introduction

Overweight and obesity are important public health problems worldwide. The percentage of the world population diagnosed with overweight is alarmingly increasing. In 2005, about 1.6 billion adults (> 15 years) were overweight (BMI 25-30 Kg/m^2), and 400 million were obese (BMI > 30 Kg/m^2). By 2015, 2.3 billion people will be overweight and more than 700 million obese.[1]

Research has shown that, in Brazil, 12.4% of men and 16.9% of women are obese. The sum of overweight and obesity reaches 50.1% for men and 48.9% for women.[2]

Studies have shown that the amount of adipose tissue and, mainly, its central distribution are associated with high blood pressure, dyslipidemia, impaired fasting glucose, and insulin resistance, which lead to an increase risk of cardiovascular disease.[3,4]

Assuming that body fat excess seems to be associated with higher morbidity and mortality rates (mainly in adults), precise, reliable, cost-effective, and broadly applicable screening tools are necessary for its assessment in population field studies and in clinical practice.[5] Anthropometry and bioelectrical impedance (BIA) have been widely used because they are simple techniques and have significant correlation with body fat.[6]

The BIA estimates total body fat by sending a low electrical current throughout the body. It is a fast, noninvasive, painless, and cost-effective method to assess body composition.[7] However, in Northeast Brazil, the BIA is not widely used in clinical practice because this device is not available in most of the health care providers.

The skinfold thickness is, among the anthropometric measurements, the most frequently used diagnostic tool in the assessment of body fat percentage due to its low cost and feasibility.[8] Because there is a relationship between subcutaneous fat and total body fat, the sum of several skinfold thicknesses can be used to predict total body fat.[9]

In order to assess central fat, anthropometric indices such as waist circumference (WC) and waist-to-height ratio (WHtR) are commonly used due to their low cost and because more sensitive methods, such as computed tomography and nuclear magnetic resonance imaging, are far expensive.[10] The Conicity Index (CI) is known to be an accurate indicator of central fat. It provides an indicator of fat located in the central region of the trunk. It is based on the concept that people tend to accumulate fat in the central region of the trunk resembling a double-cone body shape, i.e two cones with a common base at the waist, while those with less amount of fat in this region have a cylindrical body shape.[11]

The purpose of the study was to assess the correlation between body fat assessed either by bioelectrical impedance (FatBIA) or by the sum of skinfold thicknesses and anthropometric indicators of central fat distribution (WC, CI and WHtR), in order to indentify the most suitable method to asses body fat and central fat distribution in clinical practice and field studies.

Methods

Study design and sample

A cross-sectional study was carried out in 2008, enrolling undergraduate students selected from the Health Sciences Center of the Federal University of Pernambuco (UFPE), Northeast Brazil.

The sample size was estimated by gathering data from a pilot study, in which the prevalence of overweight was 18.0%, with a precision of 4.0% and a confidence limit of 95.0%. Sample size calculation was performed by using the formula proposed by Lwanga & Tye.[12] Therefore, the sample was composed of 348 subjects, selected by convenience. Pregnant or lactating women, those with chronic diseases or disabilities which could affect the anthropometric measurements were identified in the interview and excluded from the study.

Data collection

The biosocial variables analyzed were: age and sex of students and physical activity, classified in sedentary, low active, active and very active followed the criteria of the Institute of Medicine.[13]

The following measurements were obtained: weight, height, skinfold thicknesses (triceps, biceps, suprailiac and subscapular), WC and FatBIA. Weight was measured on a digital electronic scale with maximum capacity of 150 kg and precision of 100 g. Subjects were barefoot and wearing light clothes. Height was measured with a portable stadiometer (Ghrum Polar Manufacture, Switzerland) fixed on a plain wall, with 2.00 m long, with precision in millimeters. Both weight and height were measured according to techniques described by Lohman et al.[14] BMI was obtained by weight in kg divided by height squared in meters. The World Health Organization (WHO) cutoff points for

BMI were used as follows: low weight (BMI < 18.5 kg/m^2); eutrophy (BMI 18.5-24.9 kg/m^2), overweight (BMI 25.0-29.9 kg/m^2) and obesity (BMI ≥ 30 kg/m^2)[15].

Triceps, biceps, subscapular and supra-iliac skinfold thicknesses were obtained according to Lohman et al.[14] standardization, using the Cescorf Scientific Adipometer (precision of 0.05mm). Body fat percentage was estimated by the sum of the four skinfold thicknesses according to Durnin & Womersley's[16] table, for age and sex.

To assess fat distribution, WC was measured in standing position by using a non-extensible tape at the midpoint between the iliac crest and the last rib. WHO cutoff points were used as follows: high risk (WC ≥ 80 cm for females and WC ≥ 94 cm for males), and very high risk (WC ≥ 88 cm for females and WC ≥ 102 cm for males).[17]

The WHtR, a simple and effective measurement, was obtained by dividing WC (cm) by height (cm), using 0.5 as a cutoff point for males and females.[18]

The CI, which is used to assess obesity and body fat distribution, was determined by weight, height and WC with the following equation: CI = Waist Circumference (cm)/0.109√Weight (kg)/Height (m). The constant 0.109 resulted from the root of the ratio between 4π and the average density of the human body (1,050 Kg/m^3). The cutoff points adopted were 1.25 for males and 1.18 for females.[11]

BIA measurements were performed with Maltron BF-906 (Maltron, United Kingdom), with 50Hz of frequency in alternate chain of four electrodes. The device provides the percentage of fat throughout equations already programmed. The measurements were performed with the subject laid in supine position on a non-conductive surface (gym mats), with legs and arms abducted to 45º, without using jewelry or metal objects. In order to assure the accuracy of the measurements, the following recommendations were required: 4 hours of absolute fasting; not perform vigorous exercise 12 hours before; not drink alcohol 48 hours before; not use medication that could influence the hydroelectrolytic balance 7 days before, and urinate at least 30 minutes before testing.[9]

Body fat excess for males and females was defined as those with values of 16% and 24%, respectively. These cuttoff points were used because the subjects in our study were mostly young, healthy and eutrophic.

Statistical analysis and ethical considerations

The statistical analysis was performed by using the Epi-Info software version 6.04 (WHO/CDE, Atlanta, GE, USA) and the Statistical Package for Social Sciences version 12.0 software (SPSS Inc., Chicago, IL, USA). Kolmogorov-Smirnov test was used to check the normality of data, and only FatBIA was normally distributed. Correlation between FatBIA and other anthropometric indices was assessed by Spearman's correlation test. All reported *P*-values were two tailed, and those with < 0.05 were considered statistically significant.

The study protocol was approved by the Ethics Committee of the Federal University of Pernambuco (process 478789/2007-6) and each participant signed a written informed consent.

Table I
Anthropometrics characteristics of undergraduate students from the Health Sciences Center of the Federal University of Pernambuco (UFPE), Northeast Brazil, 2008

Variables	*Men* *Md (P_{25} e P_{75})*	*Women* *Md (P_{25} e P_{75})*
Age (years)	21 (20-24)	21 (20-23)
BMI (k/mg)	22,8 (21,3-24,5)	20,4 (19,1-24,3)
Body fat assessed by skinfold (%)	15,9 (12,3-20,2)	26,5 (23,4-29,6)•
Conicity Index	1,14 (1,11-1,19)	1,08 (1,05-1,11)
Waist Circumference (cm)	77,8 (73,3-84,4)	67,7 (64,2-72,9)
Waist-to-height ratio	0,45 (0,42-0,47)	0,42 (0,40-0,44)
% Fat BIA	15,2 ± 3,6°	22,3 ± 6,2°•

°Mean Values and standard deviation (normal distribution).
•Comparison of two means. p = 0.000, U test of Mann-Whitney.

Results

A total of 348 subjects (75.2% females) were included in the study. The average age was 21 years (P_{25}20 years and P_{75}23 years) for both genders. Anthropometric characteristics of participants are shown in Table 1. Regarding to physical activity, 46.6% women and 32.6% of men were classified as sedentary (p = 0.031).

According to BMI, of the 262 women, 10.3% were underweight, 8.8% were overweight and 1.9% was obese.. In relation to the BIA, 27.4 and 7.3% of the women had ≥ 24% e ≥ 32% of body fat, respectively.

According to the BMI classification, 19.8% of males were overweight and only one was obese. In relation to the BIA, 27.4 % and 7.3% of females presented ≥ 24% e ≥ 32% of body fat, respectively.

Mean FatBIA was 22.3 ± 6.2% in females and 15.2 ± 4.2% in males, both within normality range. The percentage of body fat assessed by the sum of skinfold thicknesses was 15.9% in males and 26.5% in females (table I).

According to reference values for BMI classification, both men and women presented themselves in terms of median, in the range of normal weight. Regarding WC, WHtR and CI, the values found in terms of median, for both sexes, are below the range of risk (table I).

There was a strong correlation between FatBIA and fat assessed by the skinfold thickness, WHtR and WC. However, there was a moderate correlation for men and

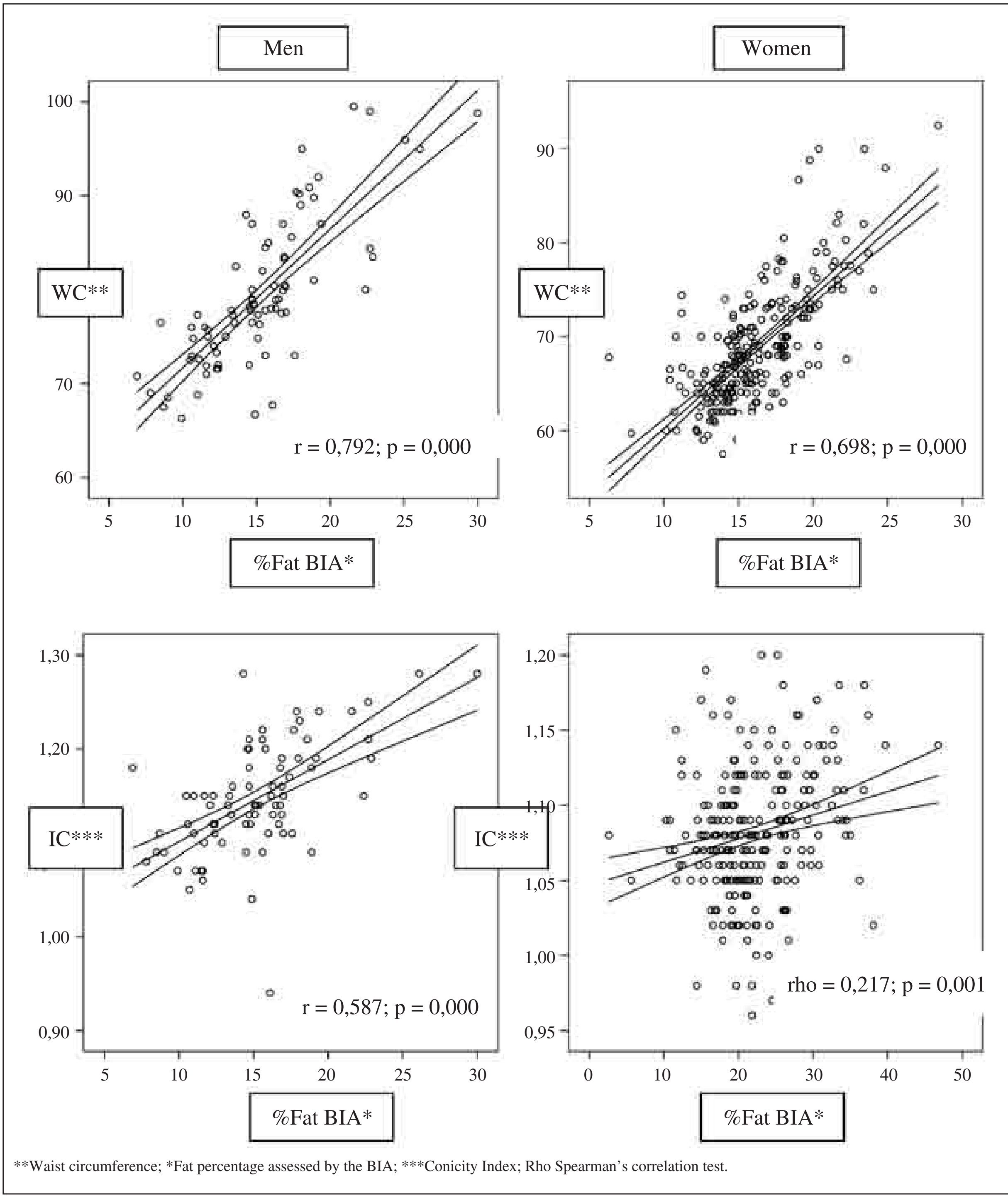

Fig. 1.—Correlation between fat percentage assessed by BIA (%FatBIA) WC and CI, according to sex in undergraduate students from the Health Sciences Center of the Federal University of Pernambuco, Northeast Brazil, 2008

a weak correlation for women regarding CI and FatBIA (Figs. 1 and 2).

Discussion

The significant correlation observed between either FatBIA or fat obtained by the sum of skinfold thickness and anthropometric indices (WC, WHtR and CI) was observed in our study population, even when adjusted for gender.

In a study designed to evaluate WC and WHtR in children and adolescents aged between 2-19 years, higher adiposity was observed between ages 18 to 19.[18] This result is in agreement with the Behavioral Risk Factor Surveillance System data that reported greater

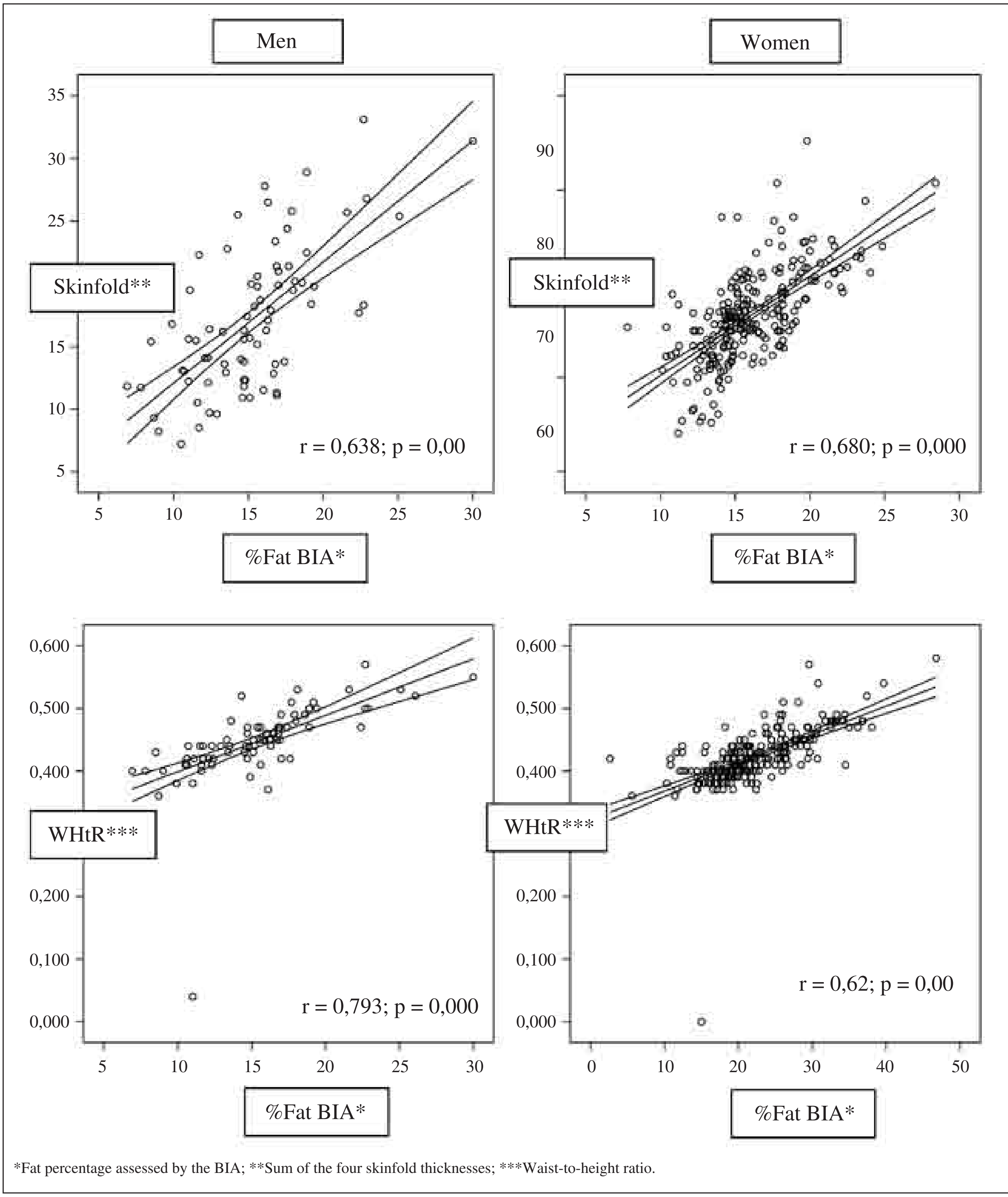

Fig. 2.—Correlation between fat percentage assessed either by BIA (%FatBIA) or by skinfold thickness and WHtR, according to sex in undergraduate students from the Health Sciences Center of the Federal University of Pernambuco, Northeast, Brazil, 2008.

increase in the prevalence of obesity between 1991 and 1998 in subjects aged between 18 to 29 years.[19] Therefore, the fact of our study have included similar young healthy adults considering that this population must be a priority in interventions regarding fat loss, mainly in the abdomen.

The subjects of the present study were young, homogeneous, and healthy, within normality ranges of BMI, body fat, WC, WHtR, and CI, except the body fat obtained by the sum of skinfold thicknesses in women and the physical activity. In fact, the highest percentage of women among sedentary students was similar to results reported by other authors. Guedes,[20] analyzing levels of habitual physical activity in adolescents found that boys were consistently more physically active than girls.

Fernandes et al. analyzed the effectiveness of the BIA by for assessing the excess of visceral and subcutaneous fat comparing WC and triceps skinfold thickness among adolescents aged 11-17 years, and found a strong correlation between FatBIA and triceps skinfold thickness in both genders (r = 0.76 for males and r = 0.77 for females).[6]

WC and WtHR are anthropometric indices largely used to predict the risk of cardiovascular diseases since they are simple and effective indicators of abdominal obesity.[17] Our findings show that both WC and WTHT had a strong correlation with FatBIA in both sexes. Fernandes et al found similar results using WC in adolescents aged 11-17 years (r = 0.82 for both sexes).[6] A higher correlation was also found by Eisenmann among children aged 3-8 years (r = 0.84).[21]

Abdominal obesity is composed of two distinct compartments of fat: subcutaneous and visceral, and the latter has a stronger association with the majority of metabolic risk factors when compared to subcutaneous abdominal adipose tissue.[22] However, in spite of different anthropometric indices are available to assess abdominal fat such as WC, WHtR, sagittal abdominal diameter (SAD), CI and waist-hip ratio (WHR),[23] these measurements represent the total abdominal area, and not the area of visceral adipose tissue in particular,[24] not being able to identify separately subcutaneous abdominal from visceral fat.[25]

Recent studies have reported that SAD is a predictor of visceral fat that shows strong correlation with cardiovascular risk factors, such as insulin resistance,[26,27,28] elevated levels of lipids and uric acid, blood pressure and metabolic syndrome[27,29]. A limitation of the use of SAD in clinical practice is the lack of consensus on the cutoffs adopted and the lack of definition of measurement protocols that best discriminate the risk of cardiovascular disease.[28]

Flegal et al.[30] observed a strong correlation between fat assessed by the dual energy absorptiometry (DXA) and WC (r = 0.85 for males and r = 0.80 for females) as well as between DXA and WHtR (r = 0.87 for males and r = 0.82 for females). WHtR showed a slightly better correlation with body fat percentage compared to WC.

A study carried out to compare different anatomic sites of WC measurements, in order to identify the most suitable site to predict FatBIA showed that the measurement performed at the midpoint between the iliac crest and the last rib (protocol recommended by the WHO) provided the best correlation,[31] which supported the use of this anatomic location when measuring WC in our study.

Several studies[18,30,31] have shown that WHtR is a better indicator for central obesity compared to WC, since it takes into account the individual's height. In our study, WHtR was more strongly correlated with FatBIA in males compared to WC. However, this result was not observed in females.

It is worth noting that participants in our study were too homogenous in terms of age and ethnic distribution, which may limit the external validity of results. Therefore, the study needs to be re-investigated in other aged groups and ethnic populations.

Conclusions

In this study the anthropometric parameters skingold thickness, WHtR and WC showed a significant correlation with BIA and can be used as proxies to identify body fat excess in young adults. Since abdominal fat is strongly associated with the risk for cardiovascular diseases, prospective studies addressing the cardiovascular outcomes in subjects with anthropometric indexes of total and central obesity altered are warranted.

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The authors declare that there are no conflicts of interest.

The study represents a original work that has not been published previously and is not been considered by another journal.

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