

Cutoff Values of the Body Fat Mass and Visceral Adiposity for the Prediction of Metabolic Syndrome in a sample of Colombian University Students

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By

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Abbreviations

MetS: metabolic syndrome

IDF: International Diabetes Federation

BF: Body Fat

VFA: Visceral Fat Area

BIA: Bioelectrical Impedance Analysis

CVD: Cardiovascular Disease

CV: Cardiovascular

CT: Computed Tomography

DXA: Dual-Energy X-ray Absorptiometry (DXA)

MRI: Magnetic Resonance Imaging

FUPRECOL: Association between Muscular Strength and Metabolic Risk Factors in Colombia

SD: Standard Deviation

BMI: Body Mass Index

WHO: World Health Organization

WC: Waist Circumference

HDL-c: High-Density Lipoprotein Cholesterol

LDL-c: Low-Density Lipoprotein Cholesterol

CI: Confidence Interval

Abstract

Background: Visceral obesity and high body fat percentages are related to metabolic syndrome (MetS) in all ethnic groups. Based on the International Diabetes Federation (IDF) definition of MetS, the aim of the study was to explore thresholds of body fat (BF%) and the visceral fat area (VFA) for the prediction of MetS among Colombian university students.

Methods: A cross-sectional study was conducted on 886 volunteers (51.9% women, mean age= 21.4 years). Weight, height, serum lipids indices, blood pressure, fasting plasma glucose, and waist circumference were measured. BF% and VFA were calculated by bioelectrical impedance analysis (BIA). MetS was defined as including ≥ 3 of the metabolic abnormalities according to the IDF definition.

Results: The overall prevalence of MetS was found to be 5.9%, higher in men compared to women. BF% and VFA was positively correlated to MetS components (all $p < 0.001$). The optimal cutoff values for BF% in predicting MetS were 31.9% (sensitivity and specificity of 78.6 and 76.7%) in women and 20.3% in men (sensitivity and specificity of 79.5 and 82.5%). ROC curve for participants showed that VFA ≥ 4.9 mm in women and 4.3 mm in men are an indicator to best predict MetS for prediction in university students from Colombia.

Conclusion: Based on the IDF criteria, both indexes were able to predict MetS in our population.

Keywords: Obesity, Adiposity, Dyslipidemia, Metabolic syndrome

Background

Obesity is one of the basic clinical conditions of metabolic syndrome (MetS), which is a cluster of risk factors for cardiovascular disease (CVD) [1]. MetS is defined by the co-occurrence in the same subjects of at least three of the following conditions: abdominal obesity, hyperglycemia, hypertension, hypertriglyceridemia, and low HDL-cholesterol (HDL-c) levels [2,3]. Currently, the growing prevalence of MetS in young adults in developing and developed countries is alarming [4-6]. According to several epidemiological studies, visceral obesity is the most predictive fat component of cardiovascular (CV) disease and events, and visceral obesity is a central feature of MetS [2,3]. For this reason, the early diagnosis of MetS in young people is a health priority since this is a way of reducing the risk of developing CVD, type 2 diabetes mellitus, and other serious illnesses [7-9].

The evaluation of adipose tissue and its distribution is a crucial factor in the detection of cardiovascular risk and MetS [10,11]. In this sense, Computed Tomography (CT) continues to be the gold standard for evaluating the distribution of body fat. Nevertheless, its high cost and low availability have made it difficult to use in large population studies. Evidently, this factor limits the possible detection of MetS in high-risk populations, especially in developing countries such as Colombia [12].

For this reason, bioelectrical impedance analysis (BIA) is the method that is most frequently used to assess body composition and calculate BF% in clinical practice, given its accuracy, simplicity, low cost, and excellent correlation with dual-energy X-ray absorptiometry (DXA), CT or magnetic resonance imaging (MRI) [13-15]. Additionally, BF% is commonly used to detect MetS, however, there is few evidence regarding its discriminatory power in the identification of MetS in the Colombian population.

Recent research highlights the usefulness of the visceral fat area (VFA), as an indicator of the function of visceral adipose tissue as a surrogate marker of cardiovascular risk in young adults [16]. Accuracy of BF% and adiposity indicators cut off values to detect metabolic risk factors in a sample of Mexican adults [17]. Other research has evaluated the applicability of VFA in the prediction of MetS and has highlighted its close relation with the components of MetS [18-20]. However, regarding the link between visceral adiposity and the risk of MetS, only a few studies have focused on the differential impacts of visceral adiposity [21-23,17] in young adults.

Our study proposes a new gender-specific index based on BIA as a way of estimating the visceral and body adiposity dysfunction associated with MetS. Apart from the study of Amato et al. [24], which used visceral adiposity index, no study has so far investigated the association between VFA estimated by BIA and surrogate markers of MetS. Based on the International Diabetes Federation (IDF) [2] definition of MetS, the aim of the study was to explore thresholds of body fat (BF%) and the visceral fat area (VFA) for the prediction of MetS among Colombian university students.

Methods

Participants

During the 2013-2016 academic years, we conducted the cross-sectional component of the FUPRECOL study (Association between Muscular Strength and Metabolic Risk Factors in Colombia) in Bogota, Colombia. The convenience sample in this study comprised 886 volunteers (51.9% female, mean age= 21.4 years [SD= 3.3]). The subjects, whose ages ranged from 18 to 35 years, were all of low to middle socioeconomic status (SES: 1–4 on a scale of 1–6 defined by the Colombian government). They were enrolled in public or private

universities in the capital district of Bogota and Cali, Colombia. Students were informed that their participation was voluntary with no penalty for not participating.

Exclusion criteria were the following: (1) self-reported history of inflammatory joint disease or neurological disorder; (2) high-performance athlete status. Volunteers received no compensation for their participation. Also, excluded from the study were subjects with a medical or clinical diagnosis of a major systemic disease (including malignant conditions such as cancer), type 1 or 2 diabetes, high blood pressure, hypothyroidism/hyperthyroidism, a history of drug or alcohol abuse, regular use of multivitamins, inflammatory (trauma, contusions) or infectious conditions, and $\geq 35 \text{ kg/m}^2$ BMI.

The Institutional Ethics Committee in accordance with the latest version of the Declaration of Helsinki approved the study (UMB N° 01-1802-2013). After reading and signing an informed consent to participate in the study, volunteers were given an appointment for a testing session at the university laboratories. Those students who agreed to participate and who had signed the informed consent form underwent the following procedures.

Physical exam and clinical variables

A person interviewed all subjects. Interview questions collected consisted of smoking status, medical history, and self-report physical activity/fitness. After completing another general information questionnaire, participants were instructed to wear shorts and a t-shirt to the physical exam. They were also required to take off all jewelry and metal objects that they might be wearing. Once the subjects were barefoot and in their underwear, their body weight was measured with an electronic scale (Model Tanita® BC 420MA Tokyo, Japan). Their height was measured with a mechanical stadiometer platform (Seca® 274, Hamburg, Germany). Their BMI (weight/height^2) was then calculated from the height (kg) and weight

(m) measurements. Weight status was evaluated according to the World Health Organization (WHO) criteria [25].

The WC (cm) was measured as the narrowest point between the lower costal border and the iliac crest. When this point was not evident, it was measured at the midpoint between the last rib and the iliac crest, using a tape measure (Ohaus® 8004-MA, Parsippany, New Jersey, USA). BF (%), and VFA (mm) were determined for BIA by a tetrapolar whole body impedance (Tanita Model BC-418®, Tokyo, Japan). The VFA area was estimated with a multiple regression equation including age, sex, anthropometric data, and body composition, as previously described [17]. A close correlation between VFA determined by BIA and that obtained by a CT scan was previously demonstrated [26,27].

Testing was scheduled to allow for a 2-hour fasting window, and participants were asked to void their bladder before testing so as to optimize muscle mass assessment accuracy. The subjects' feet were guided onto the BIA foot sensors by the raters to ensure optimal contact and centralized heel placement. All BIA measurements were performed by a trained researcher who followed the device manufacturer's instructions. For the calculation of intra-observer TEM, at least 50 subjects needed to be measured (30 men, 20 women, aged 22.3 ± 2.1 years). The corresponding intra-observer technical error (% reliability) of the measurements was 95%.

Metabolic syndrome diagnosis

After the subjects had fasted for 12 hours, blood samples were obtained from capillary sampling at 6:30AM–7:00AM. Participants were asked not to engage in prolonged exercise in the 24 hours prior to testing. The biochemical profile included the following: (i) plasma lipid triglycerides; (ii) total cholesterol, (iii) high-density lipoprotein cholesterol (HDL-c); (iv) low-density lipoprotein cholesterol (LDL-c) (by enzymatic colorimetric methods). Inter-

assay reproducibility (coefficient of variation) was determined from 80 replicate analyses of 8 plasma pools over a period of 15 days. The percentages obtained were 2.6% (triglycerides), 2.0% (total cholesterol), 3.2% (HDL-c), 3.6% (LDL-c), and 1.5% (serum fasting glucose).

Blood pressure was measured twice from the left hand with an Omron M6 Comfort (Omron® Healthcare Europe B.V., Hoofddorp, the Netherlands) while the participants were sitting still. The blood pressure monitor cuff was placed two to three-finger widths above the bend of the arm, and there was a two-minute pause between the first and second measurements. Participants were considered to have MetS if they showed three or more of the following: (1) abdominal obesity for Asiatic individuals (waist circumferences ≥ 80 cm in women and ≥ 90 cm in men); (2) hypertriglyceridemia (≥ 150 g/dL); (3) low HDL-cholesterol (< 50 mg/dL in women and < 40 mg/dL in men); (4) high blood pressure (systolic blood pressure ≥ 130 mmHg or diastolic blood pressure ≥ 85 mmHg); (5) high fasting glucose (≥ 100 mg/dL). MetS was defined in accordance with the updated harmonized criteria of the International Diabetes Federation and the American Heart Association and National Heart, Lung and Blood Institute [28].

Lifestyle co-variables

A standardized questionnaire, FANTASTIC lifestyle, was used to collect comprehensive information about substance use via a personal interview with participants [29]. Alcohol drinkers and tobacco smokers were defined, respectively, as subjects who had consumed any alcoholic beverage ≥ 1 times per week, and those who had smoked ≥ 10 cigarettes per week, for at least six months. The determination of the physical activity (PA) levels was measured using the FANTASTIC questionnaire [30]. Although the FANTASTIC only refers to PA participation in the previous week, subjects were also asked whether the pattern of PA reported in the FANTASTIC was consistent with the previous seven days. PA

was categorized as follows: insufficient: no PA practice (< 150 min/week), OR sufficient PA: five or more days of moderate-intensity PA and/or walking, in combination or alone, at least 30 min/day, accumulating a minimum of 150 min/week according to WHO recommendation. The accuracy of information about substance use and PA levels obtained from questionnaires has been validated by different experiments and described in detail elsewhere [29].

Statistical analyses

Participants characteristics obtained were given as mean values with their standard deviation (SD). Normal distribution of continuous variables was assessed using Kolmogorov-Smirnov test; for normally distributed variables. Data were then divided by sex, and a Student's t-test or Pearson's χ^2 tests were used to compare the quantitative or general category characteristics of the participants. Qualitative variables were expressed as absolute and relative frequencies. The results of quantitative variables were expressed as arithmetic mean $\pm$ SD (standard deviation). The relations between body fat, VFA, and cardiometabolic biomarkers were tested by means of partial correlation coefficients adjusted by co-variables as age, sex, tobacco, alcohol and PA levels. To predict MetS with body fat and VFA, we used Receiver Operating Characteristic (ROC) curves. Cutoff values were mathematically derived from the ROC curves, using the point on the ROC curve with the lowest value for the formula: $(1 - \text{Sensitivity})^2 + (1 - \text{Specificity})^2$. The positive likelihood ratio LR ($\text{LR}[+] = \text{Sensitivity} / [(1 - \text{Specificity})]$) and the negative likelihood ratio LR ($\text{LR}[-] = 1 - \text{Sensitivity} / [(1 - \text{Specificity})]$) were also determined. Youden's index, the distance closest to ROC (0.1), and positive likelihood ratio. All analyses were calculated with SPSS Rel.21.0 (SPSS Inc. Chicago, IL, USA). Statistical significance was set at $p < 0.05$.

Results

Table 1 presents the demographic descriptive statistics of the sample (n=896). The final sample had a mean age of 21.3 years (SD [3.2]; range [19–23 years]) and a slightly higher number of women (52.1%). Women were found to have significantly lower weight, height, WC, BP, and triglycerides than men ($p < 0.05$). According to the World Health Organization criteria, our results showed that 20.2% of the women were overweight and 5.6% were obese. In contrast, 24.1% of the men were overweight and 5.5% were obese ($p < 0.001$). The overall prevalence of MetS was 5.9% (95% CI = 4.5% to 7.6%), higher in men than in women (9.1% vs. 3.0%).

Table 1. Characteristics of subjects as a whole and by sex

Characteristics	All Population (n=896)	Women (n=465)	Men (n=431)	<i>p</i> value
Anthropometric				
Age (years)	21.3 (3.2)	21.4 (3.1)	21.3 (3.3)	0.450
Weight (kg)	64.1 (12.5)	58.9 (10.0)	69.9 (12.4)	<0.001
Height (m)	165.8 (9.0)	159.8 (6.1)	172.4 (6.7)	<0.001
WC (cm)	75.4 (9.6)	72.0 (8.1)	79.1 (9.8)	0.001
BMI (kg/m ²)	23.2 (3.7)	23.0 (3.7)	23.4 (3.6)	0.103
Body fat (%)	21.6 (8.8)	26.8 (7.2)	16.0 (6.6)	<0.001
VFA	3.8 (2.5)	3.6 (2.6)	3.3 (2.4)	0.115
Weight status*				
Underweight	29 [3.2]	16 [3.4]	13 [3.0]	<0.001
Healthy	618 [69.2]	329 [70.8]	289 [67.5]	
Overweight	197 [22.1]	94 [20.2]	103 [24.1]	
Obese	49 [5.5]	26 [5.6]	23 [5.4]	
Blood pressure				
Systolic blood pressure (mmHg)	117.9 (12.7)	112.6 (11.1)	123.7 (11.7)	<0.001
Diastolic blood pressure(mmHg)	74.3 (10.4)	72.1 (9.5)	76.8 (10.8)	<0.001
Metabolic biomarkers				
Total cholesterol (mg/dL)	142.4 (33.6)	148.7 (34.5)	135.5 (31.3)	<0.001
Triglycerides (mg/dL)	95.5 (49.2)	92.2 (47.2)	99.0 (51.0)	0.040
LDL-c (mg/dL)	84.1 (27.3)	86.1 (27.8)	81.7 (26.5)	<0.001
HDL-c (mg/dL)	44.0 (12.8)	47.8 (13.4)	39.8 (10.7)	<0.001
Glucose (mg/dL)	83.3 (13.7)	83.9 (14.2)	82.7 (13.0)	0.179
Metabolic Syndrome*				
Yes	53 [5.9]	14 [3.0]	39 [9.1]	0.001
No	840 [94.1]	451 [97.0]	389 [90.9]	
Number of components n [%]*				

0	358 [39.9]	237 [51.0]	120 [27.9]	<0.001
1	333 [37.2]	149 [32.0]	185 [42.9]	
2	152 [17.0]	65 [14.0]	87 [20.1]	
3	39 [4.4]	11 [2.4]	28 [6.6]	
4 or more	14 [1.6]	3 [0.6]	10 [2.4]	
Tobacco (≥ 10 cigarettes per week) [%]*	60 [6.7]	22 [4.7]	31 [7.2]	0.349
Alcohol (≥ 1 times per week) [%]*	90 [10.1]	42 [9.0]	50 [11.7]	0.041
PA levels (≥ 150 min per week) [%]*	296 [33.0]	147 [31.6]	152 [35.3]	<0.001

Data are expressed as mean (SD) or n [%]. *p* values are given for comparison between women and men. Significant between-sex differences (Student's *t* or Pearson's χ^2 *).

Table 2 shows the partial correlation between cardiometabolic biomarkers, anthropometrics and body composition parameters. Overall, BF% and VFA positively correlated with cardiometabolic biomarkers (all $p < 0.001$).

Table 2. Results of the partial correlation analysis between metabolic syndrome biomarkers, body fat percentage (BF%) and visceral fat area (VFA)

	Glucose (mg/dL)	HDL-c (mg/dL)	LDL-c (mg/dL)	Triglycerides (mg/dL)	Total cholesterol (mg/dL)	VFA
BF%	0.067*	0.157*	0.124*	0.126*	0.211*	0.520*
VFA	0.139*	0.225*	0.072	0.236*	0.087*	
Total cholesterol (mg/dL)	0.005*	0.311*	0.878*	0.278*		
Triglycerides (mg/dL)	0.170*	-0.186*	0.071			
LDL-c (mg/dL)	0.005*	0.124*				
HDL-c (mg/dL)	-0.134*					

Analysis adjusted by co-variables: age, sex, tobacco, alcohol and PA levels. * *p*-value <0.001.

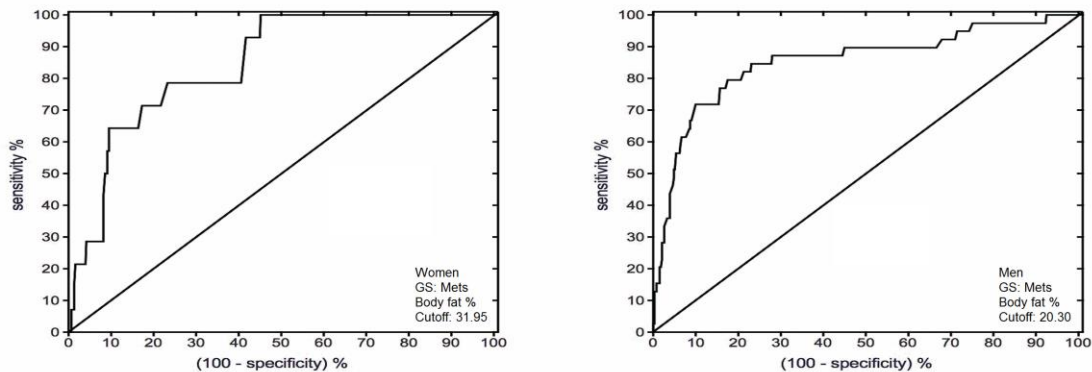
The ROC analysis showed that BF% and VFA parameters could be used to detect MetS according to the IDF criteria among Colombian university students (Table 3, Figure 1). In women, a cutoff value of 31.9% for BF% provided a sensitivity of 78.6%, an LR (+) value of 3.37, specificity of 76.7%, and an LR (–) value of 0.28. In men, a cutoff value of 20.3% for BF% had a sensitivity of 79.5%, an LR (+) value of 4.54, specificity of 82.5%, and an LR (–) value of 0.25. For the VFA, a cutoff value of 4.9 in women provided a sensitivity of 85.7%, an LR (+) value of 5.75, specificity of 85.1%, and an LR (–) value of 0.17. In men, a cutoff value of 4.3 for VFA had a sensitivity of 92.3%, an LR (+) value of 5.88, specificity of 84.3%, and an LR (–) value of 0.09.

Table 3. Area under the receiver-operating characteristic curves (AUC) for body fat percentage (BF%) and visceral fat area (VFA) to detect MetS according to the International Diabetes Federation (IDF) criteria for Colombian university students

	BF%		VFA	
	Women	Men	Women	Men
AUC (95% CI)	0.844 (0.762-0.927)	0.853 (0.779-0.926)	0.890 (0.813-0.967)	0.936 (0.899-0.973)
<i>p</i> -value	0.042	0.038	0.039	0.019
Optimal cut-offs	31.9	20.3	4.9	4.3
J-Youden	0.553	0.620	0.708	0.766
Sensitivity (%)	78.6	79.5	85.7	92.3
Specificity (%)	76.7	82.5	85.1	84.3
LR (+)	3.37	4.54	5.75	5.88
LR (-)	0.28	0.25	0.17	0.09

AUC: area under curve; LR (+): positive likelihood ratio; LR (-): negative likelihood ratio

A.



B.

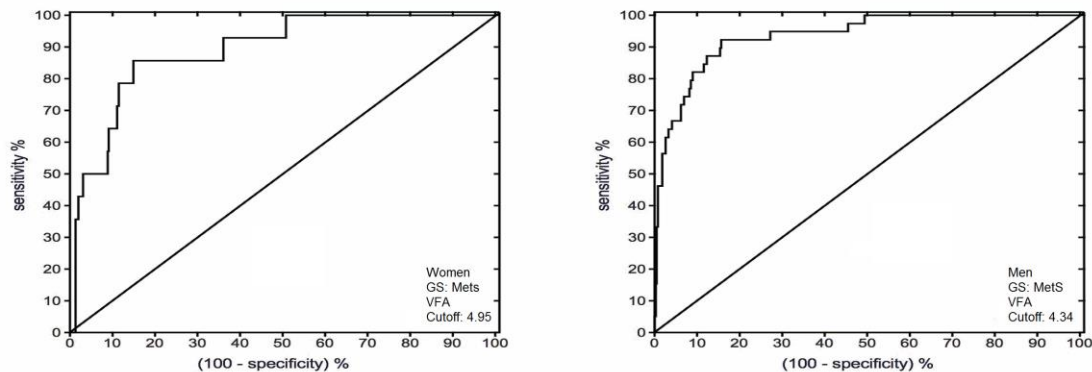


Figure 1. Receiver operating characteristic (ROC) curve of the BF% and VFA to detect metabolic syndrome according to the IDF criteria for Colombian university students. GS: gold standard; AUC: area under the curve (95% confidence interval).

Discussion

The ROC analysis showed that both the BF% and VFA had a high discriminatory power in the identification of MetS among Colombian university students. MetS is associated with the development of diabetes and CVD, which are leading causes of mortality throughout the world [31]. In fact, in the last ten years, they have reached epidemic levels in Colombia and other developing countries [32,33]. In addition, MetS has been associated with arterial stiffness, which is an evident cardiovascular risk [34]. Therefore, it is very important to develop an effective screening tool for MetS in Colombia.

Our results showed lower levels of weight, height, and WC among the women than men. This is in consonance with Liu et al. [23], who studied a population of 1698 adults in China. In all likelihood, these differences in body composition were due to sexual dimorphism [35], variation in the hydration status, and age [36]. Sex hormone is another of the possible explanations.

The triglyceride levels and blood pressure were also lower among women in comparison to those of the men. This coincides with previous research [37,38], in which this finding correlated with lower cardiovascular morbidity and mortality in the women subjects. In our study, a higher percentage of men were found to be overweight (24.1%) though obesity prevalence was slightly higher for women. In both cases, however, overweight and obesity percentages were slightly higher than in Ruano Nieto et al. [39], who found 22.24% of a sample population of Ecuadorian students to be overweight and 3.14% to be obese. The percentages in our study were also slightly higher than those of Martínez et al. [40], whose

results showed that 23.4% of a population of Chilean university students were overweight and 5.2% were obese.

Furthermore, the higher prevalence of MetS in the male subjects in our results (9.1%) does not coincide with Ruano Nieto et al. [39] who found that the estimated prevalence of MetS was 8.37% for women and 6.12% for men in a population of Ecuadorian university students. The overall prevalence of MetS in our study was also greater than that in other Latin American countries such as Chile (4.9%) and Argentina (4.1%) [40,41]. These results show that metabolic disorders are not only found in developed countries, but also in developing countries.

Of those, abdominal obesity—the most prevalent manifestation of MetS— is a marker of dysfunctional adipose tissue, and is of central importance in clinical diagnosis. The VFA, based on simple anthropometric parameters, as a surrogate marker of adipose tissue function and distribution independently correlated with cardiometabolic risk in the general population [18,26,27]. VFA showed a strong association with both insulin sensitivity (evaluated with a euglycemic–hyperinsulinemic clamp) and visceral adipose tissue (measured with MRI) [18]. Our results show striking correlations between the BF% and VFA as well as all of the cardiometabolic biomarkers analyzed (glucose, HDL-c, LDL-c, triglycerides and total cholesterol). These findings agree with Knowles et al. [20], who studied a population of young Peruvian adults and found significant correlations between the VFA and above-mentioned cardiometabolic biomarkers. Blood lipid disorders and central obesity are the key etiologic defect that defines MetS, we find all adiposity indices interested were associated with BF%. In contrast, other researchers such as Schuster et al. [42], who studied a sample of 444 young adults in Brazil, only found correlations between the VFA and glucose, HDL-

c and triglycerides. The result may be different due to degree and the prevalence varies on the basis of ethnicity, genetic susceptibility, lifestyles, geographic location and MetS definition.

According to the AUC of the ROC analysis, the VFA showed the highest AUC values (0.93 for men, 0.89 for women), followed by the BF%, (0.85 for men, 0.84 for women). In both cases, the results indicated that the VAF and BF% are good predictors of MetS though the VFA had a greater discriminatory power, especially in the case of men. The high predictive power of the VFA has been reported in certain studies though not in others. In this sense, several studies recently proposed the VFA as a valuable indicator of visceral adipose function and its increase is strongly associated with MetS in Caucasian Sicilian populations [18,19].

In contrast, another research carried out by Mohammadreza et al. [43] among Iranian adults found that VFA was not as effective parameter to predict MetS as other anthropometric indexes such as BMI, waist-to-height ratio (WHtR), and waist-to-hip ratio (WHR). In this same line, Mousa et al. [44] studied a population of young adults and found that the predictive power of BF% and VFA was limited. This discrepancy in results could be explained by the heterogeneity of the sample populations. Consequently, the applicability and usefulness of the BF% and VFA in the prediction of MetS require further studies of different populations and ethnic groups.

The principal limitation of this study was the use of cross-sectional data. Furthermore, it is also true that the hydration status of the participants could have conditioned the results of the BF% measured with BIA. The main strength of our study is the fact that our study

compared the predictive power of both the BF% and VFA while at the same time providing cutoff values for the prediction of MetS in university students from Colombia.

Conclusion

In conclusion, BF% and VFA have a high discriminatory power in the identification of MetS in Colombian university students. Apart from the differences between our cutoff points and those reported in other research in geographically different populations, the BF% and VFA values for both sexes are the first cutoff points ever obtained for a population of Colombian young adults. We demonstrated that the BF% $\geq 31.9\%$ in women and $\geq 20.3\%$ in men and VFA ≥ 4.9 mm in women and 4.3 mm in men are MetS indicators to predict MetS. This makes our study an essential point of reference for future national and international research in Colombia.

Competing interests

The authors declare that they have no competing interests.

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