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Comparison of Three Adiposity Indexes and Cutoff Values to Predict Metabolic Syndrome Among University Students

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Abstract

Purpose: Obesity and high body fat are related to diabetes and metabolic syndrome (MetS) in all ethnic groups. Based on the International Diabetes Federation (IDF) definition of MetS, the aim of the present study was to compare body adiposity indexes (BAIs) and to assess their various cutoff values for the prediction of MetS in university students from Colombia.
Methods: A cross-sectional study was conducted on 886 volunteers (51.9% woman; age mean 21.4 years). Anthropometric characteristics (height, weight, waist circumference [WC], and hip circumference [HC]) were measured, and body composition was assessed by bioelectrical impedance analysis. MetS was defined as including ≥3 of the metabolic abnormalities (WC, high-density lipoprotein cholesterol [HDL-C], triglycerides, fasting glucose, and systolic and diastolic blood pressure [BP]) in the definition provided by the IDF. The BAIs (i.e., BAI-HC [BAI], BAI-WC [BAI-w], and [BAI-p]) were calculated from formulas taking into account, height, weight, and WC, and for the visceral adiposity indexes, a formula, including WC, HDL-C, and triglycerides, was used.
Results: The overall prevalence of MetS was 5.9%, higher in men than in women. The most prevalent components were low HDL-C, high triglyceride levels, WC, and BP levels. The receiver operating characteristic curves analysis showed that BAI, BAI-w, and BAI-p could be useful tools to predict MetS in this population.
Conclusion: For women, the optimal MetS threshold was found to be 30.34 (area under curve [AUC] = 0.720–0.863), 19.10 (AUC = 0.799–0.925), and 29.68 (AUC = 0.779–0.901), for BAI, BAI-w, and BAI-p, respectively. For men, the optimal MetS threshold was found to be 27.83 (AUC = 0.726–0.873), 21.48 (AUC = 0.755–0.906), and 26.18 (AUC = 0.766–0.894), for BAI, BAI-w, and BAI-p, respectively. The three indexes can be useful tools to predict MetS according to the IDF criteria in university students from Colombia. Data on larger samples are needed.

Keywords: obesity, dyslipidemia, metabolic syndrome

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Introduction

Obesity is a major public health problem worldwide.[1] Adipose tissue is a well-known source of inflammation and a complex and highly active metabolic endocrine organ[2] that produces various cytokines.[3] Obesity and high body fat are related to diabetes and metabolic syndrome (MetS) in all ethnic groups.[4,5] In addition, a National Health and Nutrition Examination Survey reported that using the National Cholesterol Education Program showed that the age-adjusted prevalence of MetS was 44.5% among Hispanic men and 44.1% among Hispanic women.[6] Moreover, studies that included diverse Hispanics/Latinos suggested marked heterogeneity in risk factor prevalence within this population.[7,8]

High body fat is associated with increased adipocytokine production, proinflammatory activity,[9] deterioration of insulin sensitivity,[10] increased risk of developing MetS, atherosclerosis, and a higher mortality rate.[11,12] The identification of a routinely applicable indicator for the evaluation of body fat percentage (BF%), with higher sensitivity and specificity than classic parameters (such as waist circumference [WC], body mass index [BMI], and BF%), could be useful for cardiometabolic risk assessment.[13,14]

A study by Bergman et al.[15] in 2011 proposed a new method to determine BF% called the body adiposity index (BAI). The BAI is derived from hip circumference (HC) and height and was intended to be a direct validated method of estimating BF%, which was developed in a sample of Mexican Americans and validated in African American adults.[15] The equation proposed for BAI was developed with data from 1733 Mexican American adults (675 men and 1058 woman), aged 18–67, using bioelectrical impedance analysis as the standard method.[16,17]

The relationships between MetS-related phenotypes and different adiposity indexes have been studied previously,[18] an issue that the original authors of BAI did not address.[15] A recent cross-sectional study has reported that BAI could be less useful than BMI when the metabolic health risk is evaluated.[18] In this context, Snijder et al.[12] suggested that WC and waist-to-height ratio (WHtR) may be even better candidates than BMI or BAI, since they are simple (only tape measurements are required) and practical markers of ideal cardiometabolic health.

Taking into account these observations, BMI, WC, and WHtR have all been tested for their relationships to MetS, but with no consistent results across the globe.[19–21] In the Colombian adult population, to our knowledge, there is only one study, in which various adiposity indexes cutoff values were assessed for the prediction of MetS.[18] Mora-García et al.[18] suggested cutoff points for identifying MetS using anthropometric variables among adult Colombian women. These authors proposed cutoff values for WC, BMI, BAI, waist-to-hip ratio (WHR), and WHtR. Up to now, few studies have evaluated the performance of BAI in determining excess BF% in Colombian adults, but the sample sizes in the previous studies were very small.[14]

The lifestyle of the college population has changed considerably over the past 20 years due to a rapid improvement in socioeconomic status.[14] These changes, in addition to the adoption of a western lifestyle and diet, have led to a rise in the prevalence of overweight and obesity in Colombians, particularly among university students.[14] Since the index was developed in samples of Mexican American and African American individuals, the effectiveness of BAI as a predictor of risk of cardiovascular disease in other ethnicities needs further investigation.[12,18]

In this study, we propose a novel sex-specific index based on HC and height (BAI) that is able to estimate the visceral adiposity dysfunction associated with MetS. Based on the International Diabetes Federation (IDF) definition of MetS,[22] the aim of the present study was to compare BAIs and to assess their various cutoff values for the prediction of MetS among university students from Colombia.

Materials and Methods

Participants

We performed cross-sectional analyses of baseline data from participants in the FUPRECOL study (Association between Muscular Strength and Metabolic Risk Factors in Colombia), which focused on the associations among fitness, health, and noncommunicable diseases. We have recently published a complete description of the FUPRECOL study design, methods, and primary outcomes for our current cohort.[23] A convenience sample comprised 886 volunteers (51.9% woman, mean age = 21.4 years [3.3]) between the ages of 18 and 35 years, of low- to middle-socioeconomic status (1–4 on a scale of 1–6 defined by the Colombian government), and enrolled in a public or private university in the capital district of Bogota and Cali, Colombia. Inclusion criteria were as follows: no self-reported history of inflammatory joint disease or neurological disorder and not an athlete participating at an elite level. Volunteers were not compensated for their participation.

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 (BP), hypothyroidism/hyperthyroidism, a history of drug or alcohol abuse, regular use of multivitamins (may be at lower risk of MetS), inflammatory (trauma, contusions) or infectious conditions, or $\geq$35 kg/m^2 BMI were excluded from the study. The Institutional Ethics Committee, in accordance with the latest version of the Declaration of Helsinki, approved the study (Universidad Manuela Beltrán N 01-1802-2013). After reading and signing an informed consent form to participate in the study, volunteers were given an appointment for a testing session at the university laboratories. The students who agreed to participate and who had signed the informed consent form were given appointments for the following procedures:

Physical exam and clinical variables

After completing a questionnaire of general information, participants were instructed to wear shorts and a t-shirt and to remove any metal and jewelry from their person. The body weight of the subjects was measured on electronic scales (Model Tanita® BC 420MA, Tokyo, Japan) when the subjects were in their underwear and barefoot. The height of the subjects was measured using a mechanical stadiometer platform (Seca® 217, Hamburg, Germany). We calculated BMI (weight/height^2) from the height (kg) and weight (m) measurements. The weight status examined included World Health Organization criteria for obesity (BMI $\geq$30 kg/m^2) and overweight (BMI $\geq$25 kg/m^2).[24] The WC (cm) was measured as the narrowest point between the lower costal border and the iliac crest; in the cases in which this 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). HC was measured at the widest point around the buttocks with the tape horizontal and parallel to the ground using a tape with 0.1 mm accuracy (Ohaus 8004-MA, Parsippany, New Jersey).[25] WHR was calculated as WC divided by HC. WHtR was calculated by dividing WC by height in cm.[25]

A tetrapolar whole body impedance meter (Model Tanita BC 420MA, Tokyo, Japan) was used to perform the analysis of BF%, similar to previous studies.[14,23] Measurements were made with the participant in a standing position with arms and legs lying parallel to the trunk and separated, so that the thighs were not touching. Before testing, participants were required to adhere to the following bioelectrical impedance analysis (BIA) manufacturer's instructions: (i) to not eat or drink within 4 hr of the test; (ii) to not consume caffeine or alcohol within 12 hr of the test, (iii) to not take diuretics within 7 days of the test; (iv) to not do physical exercise within 12 hr of the test, and; (v) to urinate within 30 min of the test. An electrical current of 50 kHz was passed through the participant, and resistance and reactance were measured. To ensure data quality, the equipment was calibrated daily using a known calibration standard, in accordance with the manufacturer's instructions.

Body and visceral adiposity indexes calculation

BF% was calculated following the formula BAI = ((HC)/((height)$^{1.5}$) − 18)), which refers to Bergman et al.[15]; the BAI-waist circumference (BAI-w), which is replaced in the formula by the most commonly clinically used WC, BAI-w = [(WC)/([height]$^{1.5}$) − 18)]; and BAI-p, propodes by Thivel et al.[26] BAI-p = [(HC)/([height]$^{0.8}$) − 38)]. The visceral adiposity index (VAI) was calculated according to the following formula proposed by Amato et al.[27]: (i) Men: VAI = {WC/[39.681 (1.88 × BMI)]} × (TG/1.03) × (1.31/high-density lipoprotein cholesterol [HDL-C]) and (ii) Women: VAI = {WC/[36.581 (1.89 × BMI)]} × (TG/0.81) × (1.52/HDL-C).

MetS diagnostic

After fasting for 12 hr, blood samples were obtained from capillary sampling at 6:30–7:00 am. Participants were asked to not to participate in any prolonged exercise for the 24 hr before testing. The biochemical profile included the plasma lipid triglycerides, total cholesterol, HDL-C, and low-

Table 1. Characteristics Among a Sample of University Students From Colombia by Gender

Characteristics	*Women (n = 465)*	*Men (n = 431)*	*All population (n = 896)*	P
Anthropometric				
Age (years)	21.4 (3.1)	21.3 (3.3)	21.3 (3.2)	0.450
Weight (kg)	58.9 (10.0)	69.9 (12.4)	64.1 (12.5)	<0.001
Height (m)	159.8 (6.1)	172.4 (6.7)	165.8 (9.0)	<0.001
BMI (kg/m^2)	23.0 (3.7)	23.4 (3.6)	23.2 (3.7)	0.103
WHtR	0.45 (0.05)	0.46 (0.06)	0.46 (0.05)	0.033
Waist-to-hip ratio	0.74 (0.06)	0.81 (0.06)	0.78 (0.07)	<0.001
Waist circumference (cm)	72.0 (8.0)	79.1 (9.8)	75.4 (9.6)	<0.001
Hip circumference (cm)	97.0 (8.7)	97.5 (9.5)	97.2 (9.1)	0.452
VAI (mm)	3.6 (2.6)	3.3 (2.4)	3.4 (2.5)	0.115
BAI (%)	30.1 (4.8)	25.1 (4.1)	27.7 (5.1)	<0.001
BAI-w (%)	17.7 (4.4)	17.0 (4.4)	17.3 (4.4)	0.012
BAI-p (%)	28.7 (6.1)	25.0 (5.8)	26.9 (6.2)	<0.001
BF%	26.8 (7.2)	16.0 (6.7)	21.6 (8.8)	0.001
Weight status*				
Underweight	16 [3.4]	13 [3.0]	29 [3.2]	<0.001
Healthy	329 [70.8]	289 [67.5]	618 [69.2]	
Overweight	94 [20.2]	103 [24.1]	197 [22.1]	
Obese	26 [5.6]	23 [5.4]	49 [5.5]	
Blood pressure				
Systolic blood pressure (mmHg)	112.6 (11.1)	123.7 (11.7)	117.9 (12.7)	<0.001
Diastolic blood pressure (mmHg)	72.1 (9.5)	76.8 (10.8)	74.3 (10.4)	<0.001
Metabolic biomarkers				
Total cholesterol (mg/dL)	148.7 (34.5)	135.5 (31.3)	142.4 (33.6)	<0.001
Triglycerides (mg/dL)	92.2 (47.2)	99.0 (51.0)	95.5 (49.2)	0.040
LDL-C (mg/dL)	86.1 (27.8)	81.7 (26.5)	84.1 (27.3)	<0.001
HDL-C (mg/dL)	47.8 (13.4)	39.8 (10.7)	44.0 (12.8)	<0.001
Glucose (mg/dL)	83.9 (14.2)	82.7 (13.0)	83.3 (13.7)	0.179
Metabolic Syndrome*				
Yes	14 [3.0]	39 [9.1]	53 [5.9]	0.001
No	451 [97.0]	389 [90.9]	840 [94.1]	

Data are expressed as mean (standard deviation) or *n* [%].
**P* values are given for comparison between women and men. Significant between-sex differences (Student's *t*-test or Pearson's test χ^2).
BAI, body adiposity indexes; BF%, body fat percentage; BMI, body mass index; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; VIA, visceral adiposity index; WHtR, waist-to-height ratio.

density lipoprotein cholesterol (LDL-C) (by enzymatic colorimetric methods). Interassay reproducibility (coefficient of variation) was determined from 80 replicate analyses of eight plasma pools over 15 days and shown to be 2.6%, 2.0%, 3.2%, and 3.6% for triglycerides, total cholesterol, HDL-C, and LDL-C, respectively, and 1.5% for serum fasting glucose. The BP measurements were measured twice from the left hand via an Omron M6 Comfort (Omron® Healthcare Europe B.V., Hoofddorp, the Netherlands) while the participants were sitting still. The BP monitor cuff was placed two to three finger widths above the antecubital space, and a 2-min pause was allowed between the first and second measurements. MetS was defined as including ≥3 of the following metabolic abnormalities[22]: WC ≥90 cm in men or ≥80 cm in women; HDL-C <40 mg/dL in men or <50 mg/dL in women; triglyceride ≥150 mg/dL; fasting glucose ≥100 mg/dL; systolic BP (SBP) ≥130 mmHg; and/or diastolic BP (DBP) ≥85 mmHg.

Statistical analyses

Anthropometric characteristics, BP, metabolic biomarkers, and MetS components from the study sample are presented as the mean with standard deviation (SD) or frequencies [%]. Normality for selected variables was verified using histograms and Q–Q plots. Data were then split by sex, and a Student's *t*-test or Pearson's χ^2 tests were used to compare the quantitative or categorical general characteristics of the participants. BAI, BAI-w, and BAI-p indexes to detect MetS according to the IDF criteria for Colombian adults were carried out using receiver operating characteristic curves (ROC). Cutoff values were derived mathematically from the ROC curves using the point on the ROC curve with the lowest value for the following formula: $(1\text{-sensitivity})^2 + (1\text{-specificity})^2$. Area under curve (AUC), positive likelihood ratio LR (+), and the negative likelihood ratio LR (–) were also determined. All analyses were calculated with SPSS Rel.21.0 (SPSS, Inc., Chicago, IL). 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 (SD; range) of 21.3 years (3.2; 19–23) and contained slightly more women (52.1%). Women had significantly lower levels of weight, height, WHtR, waist-to-hip ratio, WC, BP, and triglycerides than men ($P < 0.05$). The VAI did not show significant differences between genders ($P = 0.115$). In women, the prevalence of overweight and obesity were 20.2% and 5.6%, and these were 24.1% and 5.5% in men, respectively ($P < 0.001$), according to the World Health Organization criteria. The overall prevalence of MetS was 5.9% (95% CI = 4.5%–7.6%), higher in men than in women (9.1% vs. 3.0%).

Table 2 shows the correlation coefficients between BIA BF% estimates and different anthropometric and metabolic measurements. The values given are for men, women, and the entire sample population. However, stratified analyses according to gender showed that for women, there were significant correlations between BF%, BAI indexes, and metabolic biomarkers in regard to BAI ($r = 0.665$, $P < 0.001$), BAI-w ($r = 0.957$, $P < 0.001$), BAI-p ($r = 0.801$, $P < 0.001$), SBP ($r = 0.290$, $P < 0.001$), DBP ($r = 0.162$, $P < 0.001$), and triglycerides ($r = 0.124$, $P < 0.001$). For men, significant correlations were found for all measurements evaluated when the group was considered in its totality, except in LDL-C and fasting glucose levels. For the entire sample, BF% had the highest coefficient of correlation with the BAI-w ($r = 0.972$, $P < 0.001$), BAI ($r = 0.726$, $P < 0.001$), and a lower correlation with total cholesterol ($r = 0.211$, $P < 0.001$), triglycerides ($r = 0.126$, $P < 0.001$), LDL-C ($r = 0.124$, $P < 0.001$), and glucose ($r = 0.267$, $P < 0.001$).

Table 2. Pearson's Correlation Coefficients Between Body Fat Percentage Measured by BIA and Different Anthropometric and Metabolic Biomarkers Among a Sample of University Students from Colombia by Gender

	Women (n = *465*)	*Men* (n = *431*)	*Overall* (n = *896*)
Anthropometric			
Weight (kg)	0.873*	0.801*	0.820*
Waist (cm)	0.823*	0.869*	0.789*
Hip (cm)	0.723*	0.708*	0.648*
WHtR	0.741*	0.866*	0.685*
BMI (kg/m^2)	0.854*	0.885*	0.653*
BAI (%)	0.665*	0.698*	0.726*
BAI-w (%)	0.957*	0.977*	0.972*
BAI-p (%)	0.801*	0.907*	0.720*
VAI (mm)	0.199*	0.338*	0.178*
Blood pressure (mmHg)			
Systolic blood pressure	0.290*	0.294*	–0.062
Diastolic blood pressure	0.162*	0.217*	0.006
Metabolic biomarkers (mg/dL)			
Total cholesterol	0.073	0.174*	0.211*
Triglycerides	0.124*	0.310*	0.126*
LDL-C	0.090	0.102	0.124*
HDL-C	–0.182*	–0.170*	0.057
Glucose	0.041	0.063	0.267*

*All reported correlation coefficients are significant at $P < 0.001$.
BIA, bioelectrical impedance analysis.

The ROC analysis showed that BAI, BAI-w, and BAI-p indexes could detect MetS according to the IDF criteria for Colombian adults (Table 2 and Fig. 1). In men, the cutoff value of 27.83 for BAI provided a sensitivity of 69.2%, an LR (+) value of 4.49, specificity of 84.6%, and an LR (–) value of 0.36. In women, the cutoff value of 30.34 for BAI provided a sensitivity of 100.0%, an LR (+) value of 2.24, specificity of 55.4%, and an LR (–) value of 0.00. For the BAI-w, the cutoff value of 21.48 in men provided a sensitivity of 78.6%, an LR (+) value of 4.65, specificity of 83.1%, and an LR (–) value of 0.26. In women, the cutoff value of 19.10 for BAI-w provided a sensitivity of 84.6%, an LR (+) value of 4.11, specificity of 79.4%, and an LR (–) value of 0.19. In regard to BAI-p, the cutoff value of 26.18 in men provided a sensitivity of 87.2%, an LR (+) value of 2.76, specificity of 68.4%, and an LR (–) value of 0.19. In women, the cutoff value of 29.68 for BAI-p provided a sensitivity of 100.0%, an LR (+) value of 2.80, specificity of 64.3%, and an LR (–) value of 0.00.

Discussion

The purpose of this study was to compare adiposity indexes and to assess their various cutoff values for the prediction of

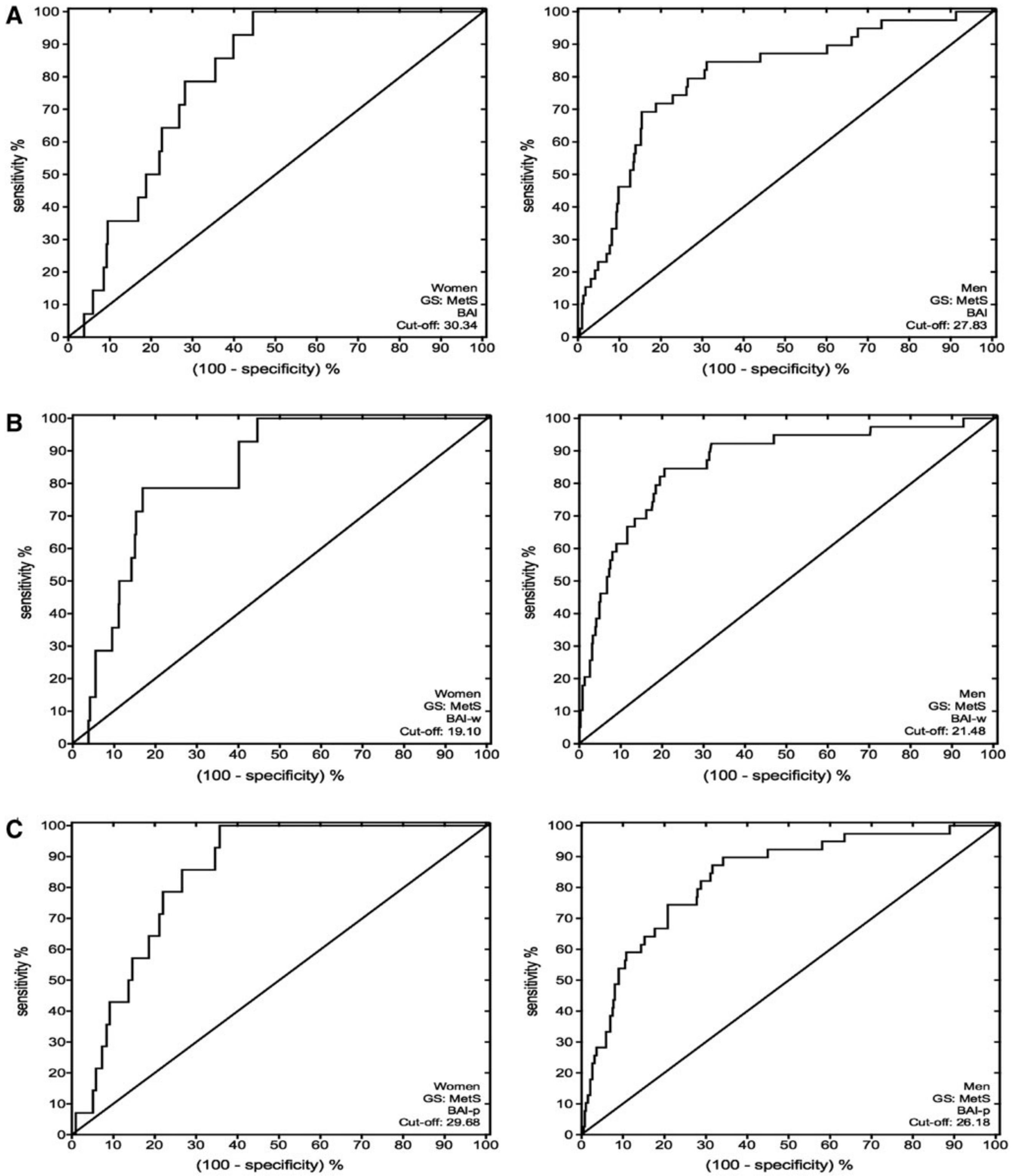

FIG. 1. ROC curve of the BAI (**A**), BAI-w (**B**) and BAI-p (**C**) indexes for ability to correctly classify subjects with MetS according to the IDF criteria for Colombian adults. BAI, body adiposity indexes; BAI-w, BAI-waist circumference; GS, gold standard; IDF, International Diabetes Federation; MetS, metabolic syndrome; ROC, receiver operating characteristic curves.

MetS in the Colombian adult population. The main findings were that all total BAIs (i.e., BAI, BAI-w, and BAI-p) predicted MetS according to the IDF criteria, displaying this association for both genders. Therefore, we conclude that total BAIs through BAI, BAI-w, and BAI-p indexes could predict MetS in the Colombian adult population.

To our knowledge, the relationships between MetS and different adiposity indexes have been previously studied[18,28–30]; however, some of these studies have been focused on specific populations (i.e., postmenopausal women, older women, etc.), requiring more in-depth study of other heterogeneous populations with different sociodemographic characteristics. In addition, BAI was suggested to have several advantages over BMI, including that it yields similar associations with BF% for men and women and may be more practical to assess in field studies, because it does not require weight measurement and can be used to reflect BF% in adults.[15] Zaki et al.[20] suggested that the BAI could be used to mirror BF% for adult men and women of differing ethnicities without numerical correction.

Our results show striking correlations between the BF% and different adiposity indexes, as well as all of the cardiometabolic biomarkers analyzed (HDL-c, triglycerides and BP). These findings agree with González-Ruíz et al.,[28] who studied a population of young Colombian adults and found significant correlations between the BAI and above-mentioned cardiometabolic biomarkers. Blood lipid disorders and central obesity are the key etiologic defect that defines MetS, and we find that all adiposity indices interested were associated with BF%.[14] In contrast, other researchers such as Schuster et al.,[30] who studied a sample of 444 young adults in Brazil, only found correlations between the body fat, 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.

In the current study, BAI, BAI-w, and BAI-p predict MetS. We observed that all BAIs exhibited high areas under the ROC curves (>0.791) for both genders ($P < 0.037$) for the prediction of MetS. In agreement with the present findings, Menke et al.[31] assessed the association between measures of adiposity and cardiovascular risk factors among 12,608 North Americans, finding that the best predictor of cardiovascular risk was WC. In our study, WC was higher in men compared with women ($P < 0.001$), showing in addition to BAI-w a high area under the ROC curves for both men (AUC = 0.831, $P = 0.038$) and women (AUC = 0.862, $P = 0.032$). Knowles et al.[32] added a specific index of visceral fat but did not observe any advantage in terms of predicting MetS-related phenotypes when compared with four other indexes of adiposity among women ($n = 952$).

In the present study, VAI did not show significant differences between genders ($P = 0.115$), so we did not use this adiposity index for the prediction of MetS. Zhang et al.[33] also compared the ability of different adiposity indexes to identify cardiometabolic risk factors in women aged 37–74 years from Asia. In agreement with the present results, the authors concluded that abdominal obesity was an important anthropometric parameter to identify metabolic risk. In that study, BMI, WC, waist-to-hip ratio, WHtR, and bioelectrical impedance-derived BF% were used to predict MetS. Contrary to our results, Zhang et al. observed that BAI was the weakest predictor of adiposity and cardiovascular risk when compared with WC, BMI, and BF%.[34]

These results differ with the present observations, since they indicate that central adiposity is more harmful to cardiometabolic health when compared with HC, which is used for the BAI calculation. However, in our study, both BAI and BAI-w significantly predicted MetS, although following the findings from Zhang et al.,[33] areas under the ROC curves were higher in BAI-w (>0.831) than in BAI (>0.791) for both genders. Zhang et al.[33] suggested that BAI is gender dependent; thus, to examine this parameter in samples composed only of women or men on larger samples are needed. Consequently, we compared adiposity indexes and

Table 3. Area Under Curves for BAI, BAI-w and BAI-p Indexes to Detect Metabolic Syndrome According to the International Diabetes Federation Criteria for Colombian Adults

	BAI		*BAIw*		*BAIp*	
	Men	*Women*	*Men*	*Women*	*Men*	*Women*
AUC (95% CI)	0.799 (0.726–0.873)	0.791 (0.720–0.863)	0.831 (0.755–0.906)	0.862 (0.799–0.925)	0.830 (0.766–0.894)	0.840 (0.779–0.901)
P-value	0.037	0.036	0.038	0.032	0.033	0.031
Optimal cutoffs	27.83	30.34	21.48	19.10	26.18	29.68
J-Youden	0.538	0.554	0.617	0.640	0.556	0.643
Sensitivity (%)	69.2	100.0	78.6	84.6	87.2	100.0
Specificity (%)	84.6	55.4	83.1	79.4	68.4	64.3
LR (+)	4.49	2.24	4.65	4.11	2.76	2.80
LR (−)	0.36	0.00	0.26	0.19	0.19	0.00

AUC, area under the receiver operating characteristic curve; LR (+), positive likelihood ratio; LR (−), negative likelihood ratio.

assess their various cutoff values for the prediction of MetS in the adult population separated by gender, finding that BAI, BAI-w, and BAI-p predicted MetS according to the IDF criteria. However, the sensitivity in women was higher for BAI (100%), BAI-w (84.6%), and BAI-p (100%) compared with men (69.2%, 78.6%, 87.2%, respectively), showing also that women had a lower percentage of specificity compared with men in BAI, BAI-w, and BAI-p (women: 55.4%, 79.4%, 64.3%; men: 84.6%, 83.1%, 68.4%). Taking this observation into account, the criteria for selecting a cutoff value (i.e., accepting or rejecting) should be considered when sensitivity is above 80% (Table 3).

To our knowledge, only two previous studies have addressed this issue in the Colombian population, obtaining similar findings to our study, since there were associations between adiposity indexes and MetS.[14,18] However, the association was observed only for WC and WHtR indexes, whereas we observed it among all BAIs (i.e., BAI, BAI-w, and BAI-p). In a study conducted on postmenopausal women, the cutoff point for BAI was 39%, whereas in the current study, the higher BAI cutoff point for women was 30.34%. However, this study was conducted in a wide age range (20–80 years), whereas our study population had an average age of 21.3 years. Considering that Colombia is a country with ethnic variations and a diverse set of population phenotypes between regions, in particular between the Caribbean region and people from Andean cities (Bogotá, Bucaramanga, Medellín, among others),[34] such results and cutoff points could be attributed to ethnic influences on body fat distribution, as has been suggested by other authors.[35]

We recognize several limitations in our study. First, it is limited by its cross-sectional design, which precludes cause–effect inferences. Further longitudinal studies are needed to establish temporal relationships between determinants of MetS and causality. Validation studies done in populations of various ethnicities have consistently indicated that the BAI tends to overestimate adiposity at lower BF% and underestimate adiposity at higher BF%.[16,17,36] Specifically, BAI does not provide valid estimates of BF% in Caucasian, European, or European American adults.[16,17,37,38] In addition, other differences, such as levels of physical activity,[39] relative length of lower limbs,[40] and body height,[41] could affect the indirect estimate of BF%.[33]

We have not considered the potential impact of recognized determinants, such as metabolic biomarkers, physical activity patterns, socioeconomic status, and physical fitness, which modulate growth and levels of adiposity. Therefore, the results that we found must be verified in other age classes and for BMI groups higher than 35 kg/m^2. Finally, we did not consider medication use, which could have potentially affected each individual MetS criterion and the estimated prevalence. The strengths of our study include a large sample size and an equal ratio of men to woman. Last of all, caution is needed when extrapolating our results to the general population and other ethnic groups.

In conclusion, total BAIs could predict MetS according to the IDF criteria in the college population. The extrapolation of an equation for estimating BF% based on BAI indexes for the university students should be viewed with caution due to Colombian ethnicity being composed of a mixture of Amerindians, Europeans, and Africans, one of the most heterogeneous populations in the world, and conferring their peculiar characteristics. We emphasize the importance of a simple and inexpensive method for adiposity estimation in low-to-middle income countries where sophisticated equipment is not widely available. Further epidemiological studies examining the utility of BAI for Latin American populations are still needed for a better understanding of the validity of this new index.

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