*Research Article*

# Waist Circumference, Body Mass Index, and Other Measures of Adiposity in Predicting Cardiovascular Disease Risk Factors among Peruvian Adults

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*Objectives*. To examine the extent to which measures of adiposity can be used to predict selected components of metabolic syndrome (MetS) and elevated C-reactive protein (CRP). *Methods*. A total of 1,518 Peruvian adults were included in this study. Waist circumference (WC), body mass index (BMI), waist-hip ratio (WHR), waist-height ratio (WHtR), and visceral adiposity index (VAI) were examined. The prevalence of each MetS component was determined according to tertiles of each anthropometric measure. ROC curves were used to evaluate the extent to which measures of adiposity can predict cardiovascular risk. *Results*. All measures of adiposity had the strongest correlation with triglyceride concentrations (TG). For both genders, as adiposity increased, the prevalence of Mets components increased. Compared to individuals with low-BMI and low-WC, men and women with high-BMI and high- WC had higher odds of elevated fasting glucose, blood pressure, TG, and reduced HDL, while only men in this category had higher odds of elevated CRP. Overall, the ROCs showed VAI, WC, and WHtR to be the best predictors for individual MetS components. *Conclusions*. The results of our study showed that measures of adiposity are correlated with cardiovascular risk although no single adiposity measure was identified as the best predictor for MetS.

## 1. Introduction

Worldwide, cardiovascular disease (CVD) is the primary cause of death; it killed an estimated 17.1 million people in 2004 [1, 2]. Historically, CVD was thought to be a disease endemic to developed countries only [3]; however, new evidence indicates that developing countries are more strongly affected by CVD than their more affluent counterparts [1–3].

The presence of metabolic syndrome (MetS) is a major risk factor for CVD [4]. According to the third report of the national cholesterol education program (NCEP) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults, MetS is defined as a co-occurrence

of specific health states, including elevated triglyceride concentrations (TG), reduced high-density lipoprotein (HDL), elevated blood pressure (BP), elevated fasting glucose (FG), and high waist circumference (WC) [5]. Body mass index (BMI), WC, Waist-to-hip ratio (WHR), waist-height ratio (WHtR) [6], and visceral adiposity index (VAI) [7] have been reported as similarly predictive for the presence of MetS in men and women.

Obesity is defined by the World Health Organization (WHO) as BMI $> 30 \, \text{kg/m}^2$, and overweight is classified as BMI $> 25 \, \text{kg/m}^2$ [8]. The established BMI cut-off points were designed for international use. Because of the concern that BMI cut-offs points might not accurately predict health risks

in all populations, the WHO established a commission and charged participants with examining available data about WC and WHR [9]. In light of concerns raised about the ability of BMI alone to predict cardiovascular risk, multiple studies have recently attempted to compare BMI with WC and other anthropometric measures of obesity, such as WHR, WHtR, and VAI, as predictors for CVD risk. In a meta-analysis of abdominal obesity indices comparing BMI, WC, WHR, and WHtR, researchers concluded that WHtR was the best predictor for both hypertension and dyslipidemia for both men and women, while BMI was the least accurate predictor of hypertension [10]. When assessing the accuracy of VAI in comparison to BMI and WC using receiver operating characteristic (ROC) curves, Amato and colleagues found VAI to be independently associated with cardiovascular events, while BMI and WC were not found to be significant discriminators [7].

Between 2000 and 2009 among Peruvians aged 15 or older, 11.5% of men and 12.5% of women were obese [11]. A recent study in Lima found the prevalence of MetS to be 21.6% in men and 29.9% in women [12]. Given that the prevalence of obesity is on the rise, and that CVD is an important cause of morbidity and mortality in Peru, its risk factors and their measurements warrant further study for this population. The purpose of the present study was to investigate the extent to which measures of adiposity (BMI, WC, WHR, WHtR, and VAI) can be used to predict elevated C-reactive protein (CRP) and selected components of MetS: elevated TG, reduced HDL, elevated BP, and elevated FG among Peruvian adults.

## 2. Materials and Methods

The data used for the present study were gathered as part of the Prevalencia de Factores de Riesgo de Enfermedades No-Transmisibles (prevalence of risk factors for noncommunicable diseases) population-based study, known as the FRENT study. Details of the study setting, sampling, and data collection procedures have been described previously [12, 13]. For the present analysis, we excluded participants taking antidiabetic drugs ($n = 30$), lipid lowering drugs ($n = 33$), or antihypertensive drugs ($n = 81$). The final analyzed sample included 1,518 participants, 952 women (62.7%) and 566 men (37.3%).

Participants were interviewed by trained health professionals using a standardized instrument, previously validated by the Pan American Health Organization (PAHO) and approved by the WHO [14]. Interview questions collected consisted of socio-demographic information, smoking status, alcohol consumption, medical history, and level of physical activity. Participants' height and weight were measured in accordance with PAHO procedures with participants wearing light clothing and no shoes [14]. Waist circumference (cm) was measured around the point halfway between the iliac crest and the sides of the lower ribs; the hip circumference (cm) was measured using the point of maximum girth around the buttocks.

Resting mean systolic and diastolic BP were calculated as an average of two measurements: the first taken after the

participant had been seated for five minutes or more, and the second measure taken 30 minutes into the interview. Blood samples were drawn from participants the day after the interview, and an individual had fasted for at least 12 hours. Aliquots of serum samples were used to determine FG, TG, HDL, and LDL concentrations using standard procedures at the Peruvian National Institute of Health Laboratory in Lima, Peru. Serum CRP concentrations were measured by an ultrasensitive competitive immunoassay (Dade Behring, Deerfield, Illinois) at the University of Washington. All laboratory procedures were conducted without knowledge of participants' medical history.

All study participants provided informed consent, and all research protocols were approved by Institutional Review Boards of National Institute of Health (Lima, Peru), Dos de Mayo Hospital (Lima, Peru), and Human Subjects Division of the University of Washington (Seattle, WA, USA).

*2.1. Variable Specification.* WHR was calculated as waist circumference divided by hip circumference, and WHtR was computed as waist circumference divided by height. VAI was calculated according to the definition established by Amato and colleagues [7], using VAI = 1 as the reference for a nonobese participant with normal TG and HDL concentrations

$$\text{Men: } \text{VAI} = \frac{\text{WC}}{39.68 + (1.88 * \text{BMI})} * \frac{\text{TG}}{1.03} * \frac{1.31}{\text{HDL}},$$

$$\text{Women: } \text{VAI} = \frac{\text{WC}}{36.58 + (1.89 * \text{BMI})} * \frac{\text{TG}}{0.81} * \frac{1.52}{\text{HDL}}.$$

$$(1)$$

BMI was calculated as weight (kg) divided by height squared (m$^2$) and categorized using WHO guidelines (lean: <18.5 kg/m$^2$; normal: 18.5–24.9 kg/m$^2$; overweight: 25.0–29.9 kg/m$^2$; obese ≥30 kg/m$^2$). In accordance with the NCEP diagnostic criteria, MetS components were defined as (1) elevated BP (mean value of systolic blood pressure ≥130 mmHg, mean value of diastolic blood pressure, ≥85 mmHg); (2) abdominal obesity (waist circumference >102 cm in men and >88 cm in women); (3) low HDL (<40 mg/dL in men and <50 mg/dL in women); (4) elevated TG (≥150 mg/dL); (5) elevated FG (≥110 mg/dL) or current drug therapy for diabetes [5].

*2.2. Statistical Analyses.* Data were analyzed using Statistical Package for the Social Sciences (version 17.0, SPSS Inc., Chicago, IL, USA) software. All analyses were stratified by gender. Pearson Chi square test was used to compare socio-demographic and behavioral characteristics between men and women. Correlation between the four selected MetS components and anthropometric measurements was evaluated using Spearman's rank coefficients. Each anthropometric measurement was divided *a priori* into tertiles and the prevalence of each MetS component was calculated for each tertile. Categories of CRP were defined by the following tertiles: <0.81 mg/L, 0.81–2.53 mg/L, and >2.53 mg/L. Elevated CRP was defined as being in the highest tertile (>2.53 mg/mL) [13]. Logistic regression procedures

TABLE 1: Socio-demographic characteristics of the study population.

| Characteristic | Women $N = 952$ | Men $N = 566$ | P-value |
|---|---|---|---|
| | $N$ (%) | $N$ (%) | |
| Age (years) | | | .001 |
| ≤24 | 151 (15.9) | 131 (23.1) | |
| 25–34 | 234 (24.6) | 146 (25.8) | |
| 35–44 | 231 (24.3) | 109 (19.3) | |
| 45–54 | 173 (18.2) | 84 (14.8) | |
| 55–64 | 109 (11.4) | 52 (9.2) | |
| ≥65 | 54 (5.7) | 44 (7.8) | |
| Education | | | .001 |
| ≤6 years | 165 (17.8) | 59 (10.7) | |
| 7–12 years | 429 (46.4) | 262 (47.5) | |
| ≥12 years | 331 (35.8) | 230 (41.7) | |
| Smoking status | | | <.001 |
| Never smoker | 800 (84.0) | 315 (55.7) | |
| Pervious smoker | 60 (6.3) | 69 (12.2) | |
| Current smoker | 92 (9.7) | 182 (32.2) | |
| Currently employed | | | <.001 |
| No | 530 (55.8) | 194 (34.4) | |
| Yes | 419 (44.2) | 370 (65.6) | |
| Alcohol consumption | | | <.001 |
| Low | 572 (60.1) | 198 (35.0) | |
| Moderate | 371 (39.0) | 330 (58.3) | |
| Excessive | 9 (0.9) | 38 (6.7) | |
| Body mass index (kg/m$^2$) | | | .002 |
| Underweight (<18.5) | 8 (0.8) | 10 (1.8) | |
| Normal (18.5–24.9) | 402 (42.2) | 219 (38.7) | |
| Overweight (25.0–29.9) | 339 (35.6) | 247 (43.6) | |
| Obesity (≥30.0) | 203 (21.3) | 90 (15.9) | |
| Leisure time physical activity | | | .002 |
| No | 217 (22.8) | 168 (29.7) | |
| Yes, <150 minutes/week | 637 (66.9) | 328 (58.0) | |
| Yes, ≥150 minutes/week | 98 (10.3) | 70 (12.4) | |

*All $P$ values were obtained using Pearson Chi Square.

were used to estimate odd ratios (ORs) and 95% confidence intervals (95% CI) of components of MetS and CRP according to combinations of overall (BMI) and central adiposity (WC) measures. For these analyses, participants were grouped *a priori* as follows: low BMI and low WC (the reference group), high BMI and low WC, low BMI and high WC, and high BMI and high WC. Because there were few subjects in the low BMI and high WC category, those with low BMI and high WC were grouped with high BMI and low WC. Potential-confounding variables were selected for assessment *a priori* on the basis of their hypothesized relationship with adiposity measures and cardiometabolic risk. The presence of confounding was empirically assessed by entering potential covariates into a logistic regression model one at a time and by comparing the adjusted and

unadjusted ORs. Final logistic regression models included covariates that altered unadjusted ORs by at least 10% [15]. For all analyses, significance was set at a $P$ value of less than .05. Finally, receiver operating characteristic (ROC) curves with area under the curve (AUC) were used to evaluate which measure of adiposity (BMI, WC, WHR, WHtR, VAI) most accurately predicted the different components of MetS.

## 3. Results

Characteristics of study participants are summarized in Table 1. The mean age of study participants was 39.3 years (38.3 years for men and 39.9 years for women). Overall, men tended to be younger, more educated, and more likely to be employed. Men reported smoking and consuming

TABLE 2: Spearman's rank correlation coefficients for anthropometric measurements and metabolic syndrome components.

| | BMI (kg/m$^2$) | WC (cm) | WHR | WHtR | VAI |
|---|---|---|---|---|---|
| | | Men | | | |
| Fasting plasma glucose (mg/dL) | 0.330 | 0.292 | 0.205 | 0.304 | 0.222 |
| Triglyceride (mg/dL) | 0.462 | 0.461 | 0.335 | 0.439 | 0.948 |
| HDL (mg/dL) | −0.291 | −0.286 | −0.188 | −0.247 | −0.664 |
| Systolic blood pressure (mmHg) | 0.273 | 0.301 | 0.255 | 0.291 | 0.188 |
| Diastolic blood pressure (mmHg) | 0.331 | 0.330 | 0.298 | 0.316 | 0.247 |
| | | Women | | | |
| Fasting plasma Glucose (mg/dL) | 0.306 | 0.301 | 0.107 | 0.301 | 0.250 |
| Triglyceride (mg/dL) | 0.437 | 0.455 | 0.226 | 0.451 | 0.933 |
| HDL (mg/dL) | −0.220 | −0.209 | −0.194 | −0.213 | −0.618 |
| Systolic blood pressure (mmHg) | 0.296 | 0.323 | 0.180 | 0.304 | 0.271 |
| Diastolic blood pressure (mmHg) | 0.265 | 0.265 | 0.164 | 0.262 | 0.227 |

The $P$ values for all Spearman's rank correlations listed are less than or equal to.001.

alcohol more frequently than women. On the basis of BMI values, men tended to be overweight (43.6% versus 35.6% of women), but women were more commonly obese (21.3% versus 15.9%, resp.).

Spearman's rank correlation coefficients were used to evaluate associations between anthropometric measurements and components MetS (Table 2). The strongest correlation was between VAI with triglyceride concentrations (men: $r = 0.948$, women: $r = 0.933$), followed by VAI with HDL concentrations (men: $r = −0.664$, women: $r = −0.618$); however, this was expected as TG and HDL are used to calculate VAI. For all measures of adiposity, triglyceride concentrations had the strongest positive correlation for men: BMI ($r = 0.462$), WC (0.461), WHtR ($r = 0.439$), and WHR ($r = 0.335$) and for women: WC ($r = 0.455$), WHtR ($r = 0.451$), BMI ($r = 0.437$), and WHR ($r = 0.226$). Of the measures of adiposity studied, BMI was most positively correlated with FG for both men ($r = 0.330$) and women ($r = 0.306$). Other than VAI, BMI was most strongly negatively correlated with reduced HDL.

Table 3 shows for both genders that the prevalence of elevated FG, BP, TG, and reduced HDL increased progressively as tertiles of each of the measures of adiposity studied increased. Table 4 shows the risk of MetS components in relation to central adiposity measures for men and women, adjusting for age, education, smoking, leisure time physical activity, and alcohol consumption. Compared to the low BMI & low WC (reference group), men with high BMI or high WC had 3.40 higher odds of having elevated TG (95% CI: 2.21–5.23), while men having both high BMI and high WC had an even higher adjusted odds ratio (AOR) (AOR: 3.89 95% CI: 2.15–7.04). For women, these AORs were 1.72 (95% CI: 1.02–2.91) and 4.64 (95% CI: 3.05–7.06), respectively. Men having either high BMI or high WC had 2.04 increased odds of reduced HDL (95% CI: 1.38–3.02), while men having high BMI and high WC had even higher odds for reduced HDL (AOR: 3.97 95% CI: 2.20–7.18). For women, these AORs were 1.29 (95% CI: 0.89–1.88) and 2.71 (95% CI: 1.95–3.75), respectively. Men having either high BMI or high WC had 1.85 higher odds for elevated BP (95% CI: 1.18–2.88),

and men in the high BMI & high WC category had even higher odds (AOR: 2.93, 95% CI: 1.61–5.32). For women in the same anthropometric measures categories, these AORs were 1.45 (95% CI: 0.82–2.58) and 2.09 (95% CI: 1.32–3.32), respectively. Men having just one of the adiposity measurements of high BMI or high WC had 1.66 higher odds (95% CI: 0.86–3.23) of having elevated FG, while men having both high BMI and high WC had 2.32 higher odds of having elevated FG (95% CI: 1.03–5.19). For women with high BMI or high WC, the AOR was 1.14 (95% CI: 0.53–2.43), and for women with both high BMI and high WC, the AOR was 2.92 (95% CI: 1.65–5.16). Men having high BMI or high WC had 1.61 higher odds of having elevated CRP (95% CI: 1.08–2.41), and these odds increased for men having both high BMI and high WC (AOR: 1.86 95% CI: 1.05–3.31). For women, this association was not significant: 1.23 (95% CI: 0.83–1.83) for those in the high BMI or high WC category, and among high BMI & high WC category: 1.15 (95% CI: 0.82–1.60).

Figures 1 and 2 show the level how adiposity measures predict each of the MetS components studied. As expected due to inclusion in the formula, VAI was the best predictor for elevated TG (area under curve [AUC] = 0.98) among men and women (AUC = 0.97), and reduced HDL for men (AUC = 0.82) and women (AUC = 0.80). VAI and BMI were the best predictors for FG for men (AUC = 0.67 and 0.67, resp.), while for women, WC and WHtR were the best predictors (AUC: 0.72 and 0.72, resp.). For elevated triglycerides, WC was the best predictor (AUC: 0.73) for men while for women, WHR was the best (AUC: 0.65). For elevated BP, WC was the best predictor (AUC: 0.66) for men while for women, WHtR was the best (AUC = 0.70). For reduced HDL, BMI was the strongest predictor for both men (AUC: 0.66) and women (AUC = 0.62).

## 4. Discussion

To our knowledge, no research has previously been published assessing the multiple adiposity measures in predicting MetS among Peruvian adults. This study has demonstrated

TABLE 3: Prevalence of metabolic syndrome components in relation to varying degree of adiposity as assessed using different anthropometric measures.

| Measurement of obesity | | Metabolic syndrome components | | | |
|---|---|---|---|---|---|
| | | Elevated FG % | High TG % | Low HDL % | Elevated BP % |
| *Among Men* | | $N = 64$ | $N = 209$ | $N = 252$ | $N = 154$ |
| Body mass index | Tertile$_1$ (<24.2) | 17.2 | 15.8 | 21.4 | 22.1 |
| (kg/m$^2$) | Tertile$_2$ (23.3–27.6) | 28.1 | 33.0 | 36.5 | 27.9 |
| | Tertile$_3$ (>27.6) | 54.7 | 51.2 | 42.1 | 50.0 |
| Waist circumference | Tertile$_1$ (<88.0) | 17.2 | 13.0 | 24.7 | 20.7 |
| (cm) | Tertile$_2$ (88.0–97.0) | 35.9 | 38.0 | 33.9 | 29.9 |
| | Tertile$_3$ (≥97.0) | 46.9 | 49.0 | 41.4 | 49.4 |
| Waist-to-hip ratio | Tertile$_1$ (<0.91) | 23.4 | 17.9 | 27.5 | 23.5 |
| | Tertile$_2$ (0.91–0.96) | 31.3 | 35.7 | 33.9 | 30.7 |
| | Tertile$_3$ (>0.96) | 45.3 | 46.4 | 38.6 | 45.8 |
| Waist-to-height ratio | Tertile$_1$ (<0.52) | 17.2 | 13.0 | 20.3 | 20.8 |
| | Tertile$_2$ (0.52–0.58) | 29.7 | 37.5 | 39.4 | 27.9 |
| | Tertile$_3$ (≥0.58) | 53.1 | 49.5 | 40.2 | 51.3 |
| VAI | Tertile$_1$ (<2.85) | 17.2 | 0.0 | 11.2 | 23.4 |
| | Tertile$_2$ (2.85–5.47) | 29.7 | 15.4 | 29.9 | 35.7 |
| | Tertile$_3$ (≥5.47) | 53.1 | 84.6 | 59.0 | 40.9 |
| *Among women* | | $N = 110$ | $N = 253$ | $N = 575$ | $N = 187$ |
| Body mass index | Tertile$_1$ (<24.1) | 16.4 | 15.0 | 26.6 | 19.8 |
| (kg/m$^2$) | Tertile$_2$ (24.1–28.0) | 23.6 | 28.5 | 33.0 | 29.9 |
| | Tertile$_3$ (>28.0) | 60.0 | 56.5 | 40.3 | 50.3 |
| Waist circumference | Tertile$_1$ (<83.0) | 12.7 | 10.3 | 29.3 | 14.4 |
| (cm) | Tertile$_2$ (83.0–93.0) | 28.2 | 35.6 | 32.9 | 30.5 |
| | Tertile$_3$ (≥93.0) | 59.1 | 54.2 | 37.8 | 55.1 |
| Waist-to-hip ratio | Tertile$_1$ (<0.87) | 20.0 | 20.2 | 28.9 | 20.9 |
| | Tertile$_2$ (0.87–0.92) | 32.7 | 30.8 | 33.6 | 36.4 |
| | Tertile$_3$ (>0.92) | 47.3 | 49.0 | 37.5 | 42.8 |
| Waist-to-height ratio | Tertile$_1$ (<0.54) | 11.8 | 12.3 | 27.0 | 15.5 |
| | Tertile$_2$ (0.54–0.61) | 26.4 | 30.8 | 34.1 | 26.7 |
| | Tertile$_3$ (≥0.61) | 61.8 | 56.9 | 38.9 | 57.8 |
| VAI | Tertile$_1$ (<3.00) | 12.7 | 0.0 | 17.9 | 15.0 |
| | Tertile$_2$ (3.00–5.59) | 21.8 | 7.9 | 32.1 | 29.9 |
| | Tertile$_3$ (≥5.59) | 65.5 | 92.1 | 50.0 | 55.1 |

FG: fasting plasma glucose; TG: triglyceride; HDL: high density lipoprotein-cholesterol; BP: blood pressure; VAI: visceral adiposity index.

the association between adiposity measures and MetS components. First, all adiposity measures were statistically significantly correlated with all MetS components studied. The prevalence of these factors increased gradually with increasing tertiles for each adiposity measure. Second, men and women with high overall and central adiposity values (i.e., high BMI & high WC) consistently had higher odds of having cardiometabolic risk factors when compared with their leaner counterparts. Notably, elevated CRP was associated with high BMI and/or high WC for men. However, no such association was observed among women. This is in agreement with previous studies that reported a gender difference CVD risk in relation to CRP levels [13]. WC was the best measure of adiposity to predict elevated BP in men.

On the other hand, WC was most predictive of elevated FG in women.

Our observations are generally consistent with some, though not all, prior studies. Medina-Lezama et al. reported that WC was a better and accurate measure of CVD risk among Andean adults [16]. Similarly, other investigators reported that WC was a better predictor of CVD risk factors (better than BMI) among non-Hispanic black, Mexican American, and non-Hispanic white participants of the third National Health and Nutrition Examination Survey [17]. Additionally, Menke and colleagues noted that WC was a better predictor of hypertension, diabetes, low HDL cholesterol, elevated triglycerides, and insulin resistance than BMI [18]. Our findings and those of others [16–18] are somewhat

TABLE 4: Risk of metabolic syndrome components in relation to visceral adiposity.

| | Low BMI & Low WC | High BMI or High WC** | | High BMI and High WC | |
| --- | --- | --- | --- | --- | --- |
| | OR (CI) | OR (CI) | P value (SE) | OR (CI) | P value (SE) |
| | | Among Women | | | |
| Elevated triglyceride | 1.00 (Reference) | 2.44 (1.50–3.98) | 0.000 (0.249) | 6.47 (4.37–9.58) | 0.000 (0.200) |
| Adjusted* | 1.00 (Reference) | 1.72 (1.02–2.91) | 0.042 (0.268) | 4.64 (3.05–7.06) | 0.000 (0.214) |
| Reduced HDL | 1.00 (Reference) | 1.28 (0.89–1.83) | 0.184 (0.183) | 2.64 (1.96–3.56) | 0.000 (0.152) |
| Adjusted* | 1.00 (Reference) | 1.29 (0.89–1.88) | 0.178 (0.191) | 2.71 (1.95–3.75) | 0.000 (0.167) |
| Elevated BP | 1.00 (Reference) | 1.99 (1.20–3.30) | 0.007 (0.258) | 3.40 (2.27–5.08) | 0.000 (0.205) |
| Adjusted* | 1.00 (Reference) | 1.45 (0.82–2.58) | 0.206 (0.294) | 2.09 (1.32–3.32) | 0.002 (0.236) |
| Elevated fasting glucose | 1.00 (Reference) | 1.70 (0.83–3.45) | 0.144 (0.362) | 4.34 (2.54–7.41) | 0.000 (0.273) |
| Adjusted* | 1.00 (Reference) | 1.14 (0.53–2.43) | 0.744 (0.389) | 2.92 (1.65–5.16) | 0.000 (0.291) |
| Elevated CRP | 1.00 (Reference) | 1.46 (1.00–2.14) | 0.049 (0.193) | 1.29 (0.95–1.76) | 0.102 (0.157) |
| Adjusted* | 1.00 (Reference) | 1.23 (0.83–1.83) | 0.310 (0.203) | 1.15 (0.82–1.60) | 0.429 (0.171) |
| | | Among Men | | | |
| Elevated Triglyceride | 1.00 (Reference) | 3.81 (2.53–5.75) | 0.000 (0.209) | 5.65 (3.20–9.96) | 0.000 (0.289) |
| Adjusted* | 1.00 (Reference) | 3.40 (2.21–5.23) | 0.000 (0.220) | 3.89 (2.15–7.04) | 0.000 (0.303) |
| Reduced HDL | 1.00 (Reference) | 2.21 (1.53–3.20) | 0.000 (0.189) | 4.33 (2.48–7.57) | 0.000 (0.284) |
| Adjusted* | 1.00 (Reference) | 2.04 (1.38–3.02) | 0.000 (0.199) | 3.97 (2.20–7.18) | 0.000 (0.302) |
| Elevated BP | 1.00 (Reference) | 1.98 (1.29–3.04) | 0.002 (0.218) | 3.67 (2.08–6.49) | 0.000 (0.291) |
| Adjusted* | 1.00 (Reference) | 1.85 (1.18–2.88) | 0.007 (0.227) | 2.93 (1.61–5.32) | 0.000 (0.305) |
| Elevated fasting glucose | 1.00 (Reference) | 2.10 (1.11–3.96) | 0.022 (0.324) | 3.61 (1.67–7.81) | 0.001 (0.394) |
| Adjusted* | 1.00 (Reference) | 1.66 (0.86–3.23) | 0.135 (0.339) | 2.32 (1.03–5.19) | 0.041 (0.412) |
| Elevated CRP | 1.00 (Reference) | 1.66 (1.13–2.43) | 0.010 (0.195) | 2.04 (1.18–3.52) | 0.010 (0.278) |
| Adjusted* | 1.00 (Reference) | 1.61 (1.08–2.41) | 0.019 (0.204) | 1.86 (1.05–3.31) | 0.034 (0.293) |

*Adjusted for age, education, smoking, leisure time physical activity, and alcohol consumption.
**Low BMI and High WC combined with High BMI and Low WC.

inconsistent with other reports. For instance, Wildman and colleagues reported that WC and BMI were equally predictive of CVD risk [19]. Moreover, results from a 2007 meta-analysis [20] suggested that measures of overall obesity (BMI) and measures of central obesity (WHR and WC) performed equally well in predicting incident type 2 diabetes. Other investigators, however, have reported that WHtR is the best predictor of CVD risk and other cardiometabolic risk factors (including hypertension and dyslipidemia) than other anthropometric measurements [19–26]. In a meta-analysis of indices of abdominal obesity, Lee et al. reported that BMI was the poorest discriminator, whilst WHtR was the best discriminator for hypertension, diabetes, and dyslipidemia for both men and women [10]. Herrera and colleagues also reported that WHtR was the most accurate measure of coronary heart disease risk, followed by WC, and BMI, in their study [22]. Finally, some have suggested that WHR, because it takes body fat distribution into account by showing abdominal and peripheral adiposity, may be the ideal measurement of adiposity [27]. However, we found WHR to have the weakest correlation and lowest AUC values of the adiposity measures for all MetS components, with the exception of elevated BP in men. VAI appeared to be the best predictor of elevated TG and low HDL in our study. However, it is important to note that triglyceride and HDL concentrations are included in the calculation of VAI values. Our observation of higher odds of cardiometabolic

risks among men and women with combined high overall adiposity and central adiposity (i.e., high BM and WC values) is biologically plausible, as intra-abdominal fat is known to be highly associated with all components of MetS [28].

As noted by Paniagua et al. [26], heterogeneity in study findings across studies that have assessed cardiometabolic risk factors in relation to indices of adiposity may be attributable to differences in race/ethnicity, age, and gender distributions of participants across study populations. A number of investigators have reported differences in the predictive value of obesity indicators according to ethnicity [29, 30]. Vazquez et al. noted that central obesity was a stronger predictor of incident type 2 diabetes than were measures of total body fat [20]. However, measures of overall obesity were better predictor of type 2 diabetes in US and European Caucasian [31]. Though no anthropometric measurement was consistently the best predictor for MetS among the present population of Peruvian adults, we noted that VAI, WC, and WHtR to be the best predictors for individual MetS components.

Strengths of our study include the extensive CVD risk-factor data available for study participants and the unique opportunity to assess these risk factors in a population-based sample representative of adult residents of Lima and Callao, Peru. Limitations of our study include the cross-sectional design which did not allow us to assess the temporality of the relation between the adiposity measures and metabolic
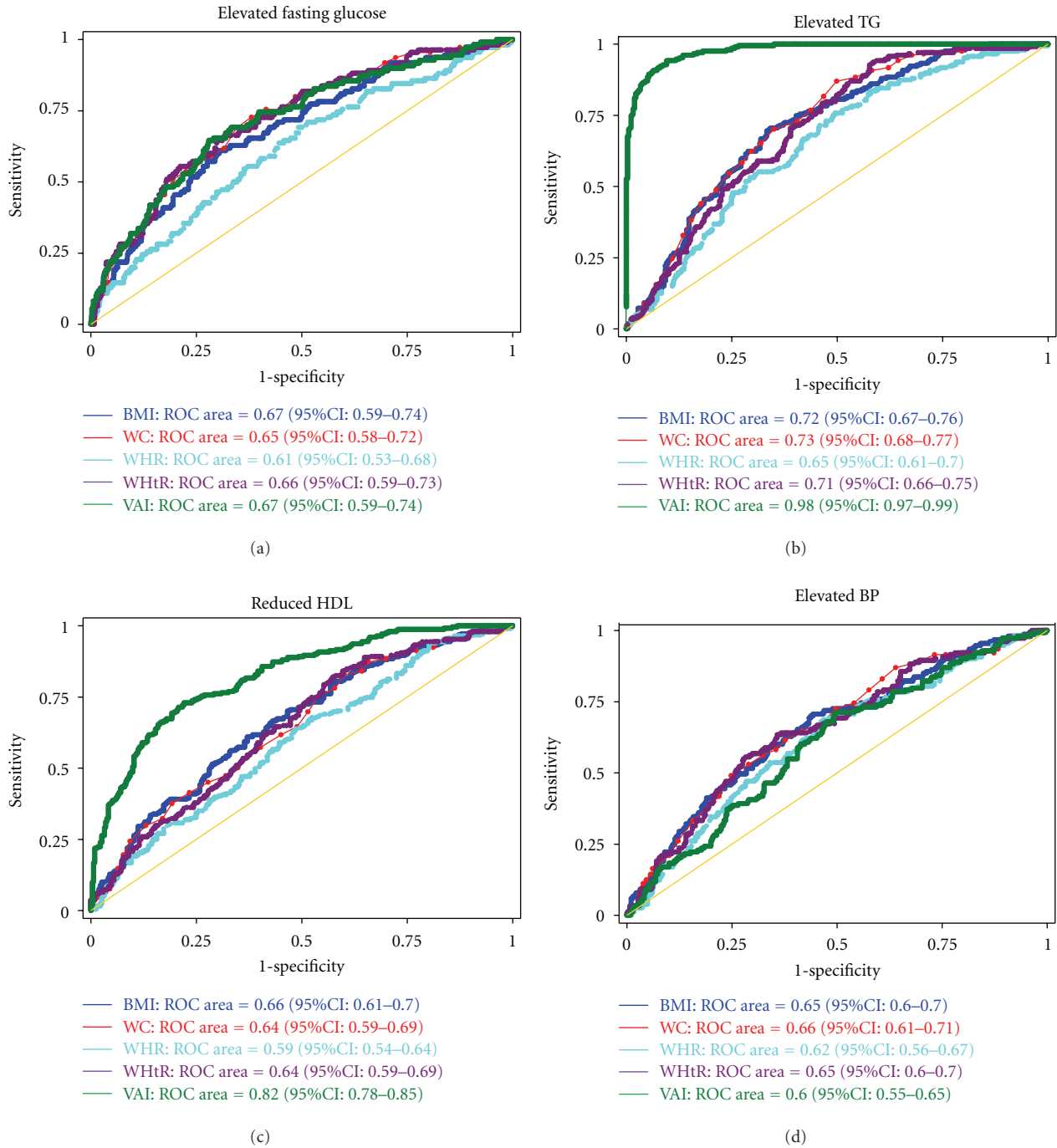
Figure 1: Receiver operating characteristic (ROC) curves with area under curve (AUC) and 95% confidence intervals of body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) for predicting cardiovascular disease risk factors among Peruvian men.

syndrome components. Some nonsystematic error in reporting of smoking history, physical activity, and other covariates may have occurred. Additionally, despite adjustment for multiple confounders, residual confounding by unmeasured or imprecisely measured covariates may persist. Finally, concordance of our study results with previous reports from geographically, racially, and ethnically diverse populations, in part, attenuates these concerns.

Although the best adiposity measurement for predicting CVD remains controversial, in our study most measures of adiposity were correlated with the cardiometabolic factors of interest. The results of our study underscore the importance of using simple, broadly applicable measures of adiposity such as WC and WHtR in community-based epidemiologic studies. These relatively inexpensive and easily obtained measures are useful for assessing cardiovascular
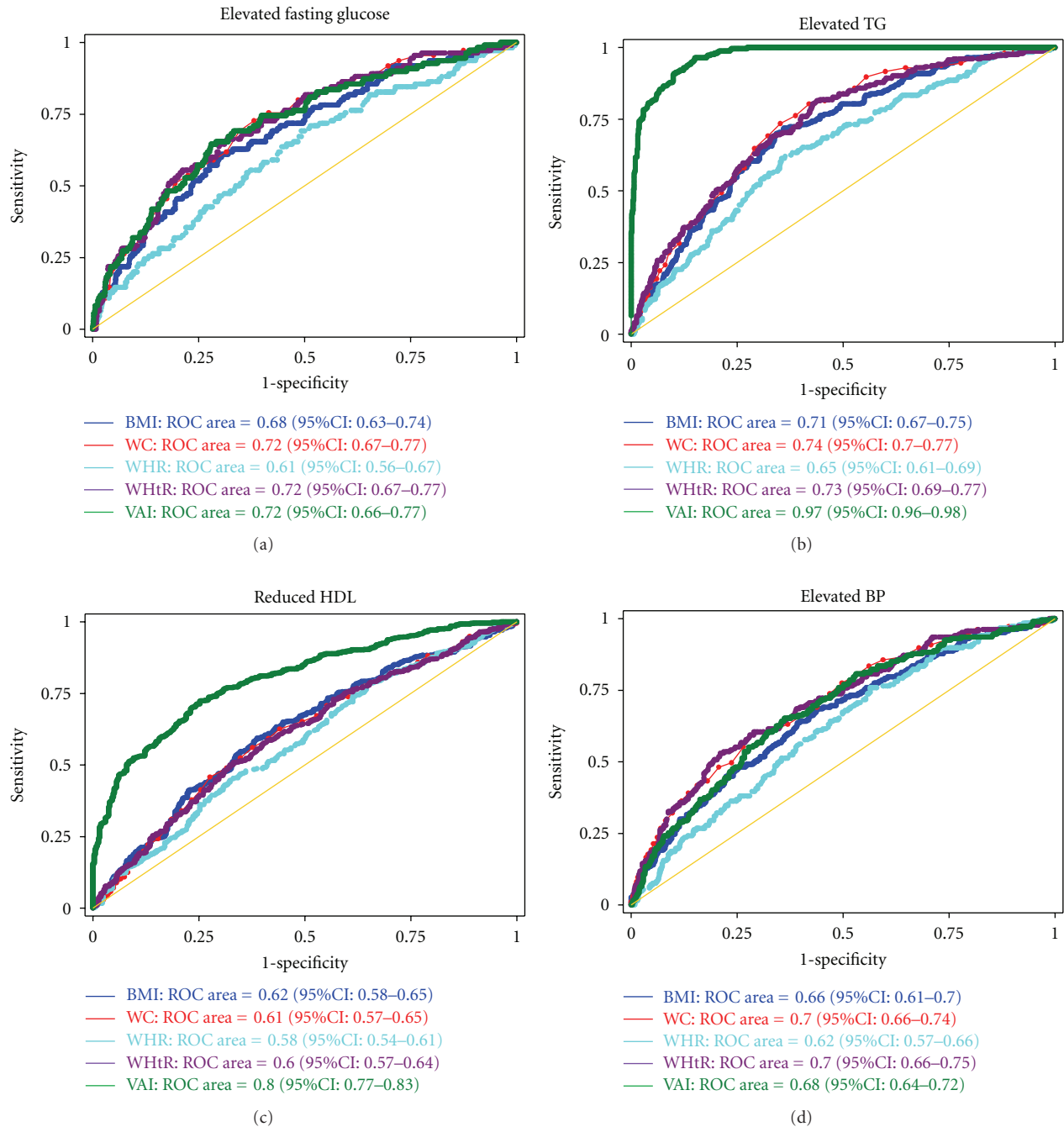
Figure 2: Receiver operating characteristic (ROC) curves with area under curve (AUC) and 95% confidence intervals of body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), and waist-to-height ratio (WHtR) for predicting cardiovascular disease risk factors among Peruvian Women.

disease risk in nonclinical settings. Though the various measurements each have advantages and disadvantages, it is evident that, to date, no single measurement can be identified as the optimal choice for CVD prediction on its own. To this effect, the United States National Institutes of Health (NIH) now recommends the use of WC in conjunction with BMI as a complementary indicator of health risk among normal and overweigh subjects [32]. The overall results of our study showed that measures of

adiposity are correlated with cardiovascular risk among Peruvian adults. Investigators in Latin America have called for a country-specific epidemiological data to help bring public health policy changes for surveillance, prevention, and intervention [33]. The high prevalence of MetS, obesity, and observed associations of cardiometabolic risks with adiposity measures reported in this study calls for increased efforts aimed towards clinical preventive services to identify and control the existing metabolic abnormalities among

patients. Additionally, development and implementation of public health programs that promote healthful behaviors including increased physical activity, eating balanced diets, and avoidance of adult weight gain are needed to help reduce the burden of noncommunicable diseases among Peruvian adults.

## Conflict of Interests

The authors declare that they have no conflict of interests.

## Authors' Contributions

L. Revilla, TTC, M. B. Yasuda, and S. E. Sanchez participated in the design of the study and carried out data collection. K. M. Knowles and L. L. Paiva participated in statistical analysis, interpretation of results, and drafting the paper. S. E. Sanchez and N. D. Yanez led the analysis, supervised research trainees, and participated in interpretation of results and in drafting the paper. B. Gelaye and M. A. Williams conceived and participated in data analysis, interpretation of results, and providing critical review of the paper. All authors read and approved the final paper. K. M. Knowles and L. L. Paiva contributed equally to this work.
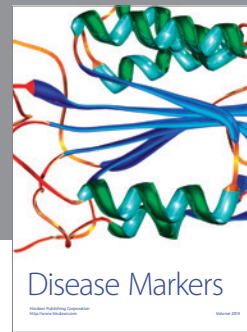
## Acknowledgments

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