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# Interethnic differences in the accuracy of anthropometric indicators of obesity in screening for high risk of coronary heart disease

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## Abstract

**Background—**Cut points for defining obesity have been derived from mortality data among Whites from Europe and the United States and their accuracy to screen for high risk of coronary heart disease (CHD) in other ethnic groups has been questioned.

**Objective—**To compare the accuracy and to define ethnic and gender-specific optimal cut points for body mass index (BMI), waist circumference (WC) and waist-to-hip ratio (WHR) when they are used in screening for high risk of CHD in the Latin-American and the US populations.

**Methods—**We estimated the accuracy and optimal cut points for BMI, WC and WHR to screen for CHD risk in Latin Americans ($n$=18 976), non-Hispanic Whites (Whites; $n$=8956), non-Hispanic Blacks (Blacks; $n$=5205) and Hispanics ($n$=5803). High risk of CHD was defined as a 10-year risk ≥20% (Framingham equation). The area under the receiver operator characteristic curve (AUC) and the misclassification-cost term were used to assess accuracy and to identify optimal cut points.

**Results—**WHR had the highest AUC in all ethnic groups (from 0.75 to 0.82) and BMI had the lowest (from 0.50 to 0.59). Optimal cut point for BMI was similar across ethnic/gender groups (27 kg/m$^2$). In women, cut points for WC (94 cm) and WHR (0.91) were consistent by ethnicity. In men, cut points for WC and WHR varied significantly with ethnicity: from 91 cm in Latin Americans to 102 cm in Whites, and from 0.94 in Latin Americans to 0.99 in Hispanics, respectively.

**Conclusion—**WHR is the most accurate anthropometric indicator to screen for high risk of CHD, whereas BMI is almost uninformative. The same BMI cut point should be used in all men and women. Unique cut points for WC and WHR should be used in all women, but ethnic-specific cut points seem warranted among men.



### Keywords

coronary heart disease; screening; ethnic group; Latin America; NHANES


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## Introduction

Obesity is a recognized risk factor for the development of cardiovascular diseases and for all-cause mortality among ethnic groups in the United States.1,2 Also among Latin Americans, that is, Hispanics living in their country of origin, obesity doubles the risk of coronary heart disease (CHD)3 and seems to contribute to an excess of 18 to 49% in the risk of coronary events.4 In view of the large impact of obesity on cardiovascular risk, anthropometric indicators of obesity are commonly used as a tool to identify individuals and populations at high risk of cardiovascular events.

Body mass index (BMI) is a measure of overall obesity, whereas waist circumference (WC) and waist-to-hip ratio (WHR) are used as indicators of abdominal obesity. Although these obesity indicators have been independently associated with CHD incidence and mortality in different populations,5-7 several investigators and public health organizations have recently questioned whether cut points derived from Whites from Europe and the United States are appropriate for use in other populations.8-10 For instance, the World Health Organization (WHO) has recently suggested lowering BMI action cut points to 23 and 27.5 kg/m$^2$ for Asians,8 and the International Diabetes Federation's guidelines for assessing metabolic syndrome recommends the use of South Asian's WC cut points for Latin Americans and makes no recommendation for cut points among Blacks from the United States.11 In this study we used data from six Latin-American countries and from the United States National Health and Nutrition Examination Survey (NHANES) to compare the accuracy of BMI, WC

and WHR, that is, their ability to correctly classify individuals as having a high or a low risk of CHD. We also estimated ethnic and gender-specific optimal cut points for these anthropometric indicators when they are used in screening for high risk of CHD.

## Methods

Study data came from the Latin-American Consortium of Studies in Obesity, a partnership of studies on the burden, etiology and consequences of obesity in the region (http://www.pophealth.wisc.edu/laso). Eight health surveys from six countries (Chile, Colombia, Dominican Republic, Perú, Puerto Rico and Venezuela) were included in this analysis (Table 1).4,12-18 All participants in these studies were categorized as 'Latin Americans' for the purpose of the present analysis. Each survey was approved by an Institutional Review Board and all participants provided their informed consent. We certify that all applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during this research. Standing height and weight were measured in all surveys with the participants wearing light clothing and no shoes. WC was measured at the umbilical level in three studies,4,16,18 at the midpoint between the lowest rib and the iliac crest in three studies,12,13,15 at the high point of the iliac crest in one study17 and was not measured in another.14 Hip circumference was only measured in five studies, at the maximum extension of the buttocks.4,13,16-18 Blood pressure measurements were conducted at least twice in all but one study15 following standard recommendations.21 Blood samples were obtained in all studies after ≥8 h of fast and serum glucose, total cholesterol and high density lipoprotein cholesterol were measured enzymatically by automated methods.

Data from the United States population came from NHANES III (1988-1994)19 and from NHANES 1999-2000, 2001-2002 and 2003-2004 (Table 1).20 Sampling weights were not used in the calculation of area under receiver operator characteristic (ROC) curve (AUC). However, failure to account for sampling weighting does not change the consistency of the AUC estimates, because probability weighting does not affect either the shape or location of the conditional distributions.22 Racial/ethnic categories identification in NHANES was self-reported. Due to sample size limitations, native Americans and Asian Americans from the United States were excluded from this analysis. WC was measured at the high point of the iliac crest and hip circumference was measured at the maximum extension of the buttocks (only in NHANES III). Three to four blood pressure measurements were taken following standard procedures23 and blood glucose and lipids were measured by automated methods. NHANES data were statistically weighted to maintain the representativeness of the sample for the US population.24

In the absence of incident data, ethnic and gender-specific optimal cut points for BMI, WC and WHR were identified as those that maximized the correct classification of individuals according to their expected risk of CHD. We used the Framingham equation to estimate the expected 10-year risk of CHD in 30- to 74-years old men and women.25 Persons with an estimated 10-year risk of CHD ≥20% were considered at 'high risk', because currents standards of care recommend aggressive risk reduction and selective use of proven drug therapies in these individuals.26,27 We used multivariate imputation by chained equations to fill out missing values and generated 10 imputed datasets, separately for each study, to minimize selection bias due to missing data.28 One strength of this method is that it does not assume a particular form for the multivariate distribution of the data, that is, multivariate normal. The imputation model included sociodemographic variables (age, gender, race, education and area of residency), anthropometric indicators (weight, height, waist and hip circumference) and cardiovascular risk factors (blood pressure, smoking status, plasma glucose, total, LDL- and HDL-cholesterol and triglycerides). Non-normally distributed

variables were log transformed to improve the model's fit. Ten cycles of regression switching were carried out to generate each imputed dataset as recommended.28 The parameters of interest were averaged across the 10 imputed datasets, using Rubin's formula.29 For our imputation model, we assumed that data were missing at random, that is, missing values, such as blood pressure, could be predicted with observed values in other variables, such as the subject's gender, age, and BMI, among other variables. In this scenario, an analysis based on multiple imputation is likely to yield estimates that are less biased than those from an analysis based on complete data.30

We drew empirical ROC curves and calculated the AUC to assess the accuracy of each anthropometric indicator in screening for high risk of CHD. We also calculated the sensitivity of each marker at a fixed specificity of 80%, because a false-positive rate ≥20% was deemed unacceptable for screening purposes. ROC curves and AUCs were estimated nonparametrically using the method of placement values,31-33 and confidence intervals were obtained by bootstrapping. Finally, we tested if the accuracy of BMI, WC and WHR differed in the whole sample as well as within groups defined by ethnicity, gender and age (<60 years vs ≥60 years).

For the estimation of ethnic and gender-specific optimal cut points for each indicator we gave equal weight to the consequences of misclassifying individuals, that is, we gave the same importance to false-negative and false-positive results and used a prevalence of high risk of CHD of 50% in our calculations.34 This approach fully exploits the data available and facilitates comparison of the different anthropometric indicators.34 Standard errors for the cut points were obtained by bootstrapping. Optimal cut points were estimated in a randomly selected 50% training sample from a randomly selected imputed data. The sensitivity and specificity of these cut points were evaluated in the remaining 50% validation sample, because cut point performance would appear better if assessed with the same data from which cut points were derived than it will appear in an independent dataset. We also compared the sensitivity and the specificity of study-derived and standard cut points in the validation sample. This approach provides a valid comparison, because the validation sample was not used to estimate study-derived or standard cut points. For BMI and WC, we used the standard cut points recommended by the WHO,35 and for WHR those recommended by Bray (1.00 for men and 0.90 for women).36 Ethnic and gender-specific cut points were compared using a *t*-test and pooled estimates were calculated using a random effects model.37

## Results

This study included 18 976 participants from Latin America, 10 878 participants from NHANES III and 9086 from NHANES 1999-2004, who were 30-74 years old (Table 1). The variable with the largest percentage of missing/imputed values was blood glucose at 11.9%. The average BMI was lowest in Latin-American women and men (26.2 and 27.2 kg/$m^2$, respectively) and highest in white men (28.5 kg/$m^2$) and black women (31.8 kg/$m^2$; Table 2). Latin-American men and women also had the smallest WC and WHR of all ethnic groups, whereas Hispanic men and women had the largest WHR, and white men and black women had the largest WC. Latin Americans had the lowest levels of all cardiovascular risk factors, with the exception of average systolic and diastolic blood pressure. Moreover, the prevalence of high risk of CHD ranged from 9.3% in Hispanics to 13.3% in Latin Americans.

WC was strongly correlated with BMI ($r$=0.83) and WHR ($r$=0.67), whereas the correlation between BMI and WHR was only moderate ($r$=0.28). In all ethnic groups, WHR had the highest accuracy in screening for high risk of CHD, followed by WC and then by BMI

(Table 3). Correspondingly, the AUCs for WHR ranged from 0.75 in Latin Americans to 0.82 in Whites; those for WC ranged from 0.62 in Blacks to 0.70 in Whites; and those for BMI from 0.50 in Blacks to 0.59 in Whites. Moreover, all indicators performed significantly better in Whites, and within each ethnic group all were consistently more accurate in women than in men and in individuals <60 years of age than those in ≥60 years old (data not shown).

The sensitivity reached at a fixed specificity of 80% for BMI was very low in all ethnic groups, with a maximum of 25% in Whites (Table 4). Similarly, for WC the maximum sensitivity was only 41% among Whites. On contrast, the sensitivity of WHR varied from 56% among Latin Americans to 67% among Whites. Within each ethnic group, the differences in sensitivity at 80% specificity were all statistically significant ($P<0.05$). Similar to the AUCs, all three indicators had the highest sensitivities in younger individuals and in women.

Optimal cut points among women for BMI ranged from 27.4 kg/m$^2$ in Whites to 28.3 kg/m$^2$ in Blacks; however, there were no significant differences between ethnic groups and the pooled average cut point in women was 27.8 kg/m$^2$ (Table 5). In men, optimal BMI cut points were homogeneous among ethnic groups and varied from 25.4 kg/m$^2$ in Hispanics to 27.9 kg/m$^2$ in Whites, with a pooled average of 26.6 kg/m$^2$. In addition, within each ethnic group there were no significant gender differences in the optimal BMI cut points. For the whole population, the pooled average of the optimal cut point for BMI was 26.7 kg/m$^2$ (95% confidence interval: 26.0-27.3).

Among women, optimal cut points for WC were homogeneous among ethnic groups and ranged from 93.0 cm in Latin Americans to 96.8 cm in Whites, with a pooled average of 94.0 cm (Table 5). In contrast, among men, the WC optimal cut points varied significantly among ethnic groups, from 91.0 cm in Latin Americans to 102.1 cm in Whites, with a pooled average of 96.8 cm. Moreover, WC optimal cut points were significantly higher in white men and Hispanic men than in women of the corresponding ethnicity. However, in Latin Americans and Blacks WC optimal cut points were similar in men and women.

Optimal cut points for WHR among women ranged from 0.87 in Latin Americans to 0.93 in Blacks, with a pooled average of 0.91 (Table 5). Among men, WHR optimal cut points varied from 0.94 in Latin Americans to 0.99 in Hispanics, with a pooled average of 0.96. In addition, WHR optimal cut points were significantly higher in men than in women in Whites, Hispanics, and Latin Americans. In contrast, WHR optimal cut points were similar in black men (0.95) and women (0.93).

The sensitivity and specificity of a BMI≥30 kg/m$^2$ (WHO definition) were 47 and 69% in women (Table 6). Reducing the cut point to 28 kg/m$^2$ resulted in a higher sensitivity of 63% (relative increment of 35%) and a lower specificity of 57% (relative reduction of 17%). Among men, the sensitivity and specificity of the WHO definition were 28 and 78%, respectively. Reducing the cut point to 27 kg/m$^2$, the sensitivity was increased to 52% (relative increment of 85%) and the specificity was reduced to 56% (relative reduction of 28%). When a unique cut point of 27 kg/m$^2$ (our pooled estimate for women and men) was used, it yielded a sensitivity of 54% and a specificity of 52%.

In women, abdominal obesity defined as a WC≥88 cm yielded a sensitivity of 83% and a specificity of 42% (Table 6). Increasing the cut point to 94 cm results in a lower sensitivity of 71% (relative reduction of 15%) and a higher specificity of 58% (relative increment of 40%). A WHR cut point of 0.90 yielded a sensitivity of 68% and a specificity of 66%. When the cut point was increased to 0.91 in women (our pooled estimated), the sensitivity was

reduced to 62% (relative reduction of 9%) and the specificity was increased to 70% (relative increment of 7%).

In men, a WC cut point of 102 cm yielded a sensitivity of 45% and a specificity of 73% (Table 6). This cut point coincided with the one estimated from our data in Whites. Implementing the ethnic-specific cut points derived from Blacks (95 cm), Hispanics (99 cm) and Latin Americans (91 cm) the corresponding sensitivities and specificities were 69 and 53, 56 and 66, and 80 and 38%, respectively. On the other hand, using the pooled cut point of 97 cm (Table 5) yielded a sensitivity of 62% and a specificity of 60%.

A definition of abdominal obesity in men as a WHR≥1.00 yielded a sensitivity of 51% and a specificity of 79%. The implementation of ethnic-specific cut points in Whites (0.98), Blacks (0.95), Hispanics (0.99) and Latin Americans (0.94) yielded sensitivities and specificities of 62 and 70, 78 and 52, 56 and 75, and 82 and 46%, respectively. On the other hand, using the pooled cut point of 0.96 (Table 5) yielded a sensitivity of 74% and a specificity of 58%.

## Discussion

Our results indicate that WHR is the anthropometric indicator with the highest accuracy to screen for high risk of CHD, followed by WC and then by BMI. These results were consistent in Whites, Blacks, Hispanics and Latin Americans, and across age and gender groups. Although BMI is the most used indicator in clinical practice, its accuracy in identifying high risk of CHD seems very limited. In fact, the AUC results indicate that if a patient with high risk (case) and another with low risk of CHD (non-case) are selected at random, BMI will be higher in the case slightly over 50% of the time, whereas WC and WHR will be higher 65 and 80% of the time, respectively. Moreover, in the best scenario (among Whites), for a fixed 20% false-positive rate BMI will identify only 2/8 cases whereas WC and WHR will identify 2/5 and 2/3 cases, respectively. These findings are consistent with those from a large multinational case-control study38 and from a prospective study among Europeans39 in which the association with CHD was strongest for WHR, intermediate for WC and weakest for BMI.

We also found that the accuracy of all three anthropometric indicators is higher in Whites compared to the other ethnic groups. This may be explained by differences in the strength of the association between measurements of obesity and cardiovascular risk across ethnic groups. In support of this, Okuson *et al.*40 found a stronger association between overall and abdominal obesity and the coexistence of hypertension and diabetes in Whites than in Blacks and Mexican Americans in the US population. On the other hand, the better performance of indicators of obesity in Whites may also reflect a more accurate estimation of the risk of CHD in this ethnic group, because the Framingham equation was originally developed on a predominantly white cohort.

Interestingly, the accuracy of the three indicators of obesity was higher in young individuals (<60 years old) and in women in the four ethnic groups. Similar differences in the accuracy by age and sex have been previously reported in populations from the US41 and Latin America.42

In contrast to what has been suggested for Asians,8-10 we found that a unique optimal cut point for BMI can be used in individuals from different ethnic backgrounds, as well as in men and women. This is consistent with BMI being almost uninformative in screening for high risk of CHD. The BMI optimal cut point found in our study (~27 kg/m$^2$) was slightly higher than those from previous studies. For instance, in Brazilians aged 30-74 years Pitanga *et al.*43 found that the best cut points to screen for high risk of CHD were 24 kg/m$^2$ in men

and 26 kg/m$^2$ in women. Also, in Whites from the United States, Zhu *et al.*44 found optimal cut points of 26 kg/m$^2$ in men and 25 kg/m$^2$ in women in screening for at least one cardiovascular risk factor. Overall, a definition of obesity as BMI≥30 kg/m$^2$ had a very low sensitivity particularly among men (28%). Lowering this cut point to 27 kg/m$^2$ in all ethnic groups would increase sensitivity to 52% in men and 63% in women. Whether this finding could be extrapolated to other ethnic groups is uncertain.

The optimal cut points for the indicators of abdominal obesity differed significantly by gender in Whites and Hispanics but not in Blacks or Latin Americans. This finding provides support for the current recommendation of using gender-specific cut points for WC and WHR in Whites. It is also consistent with those from Okosun *et al.*,41 who found gender-dependent cut points for WC in Whites and Hispanics but not in Blacks, and those from Sanchez-Castillo *et al.*,42 who found the same WC cut point in Latin-American men and women. Further efforts aimed to validate anthropometric indicators of abdominal obesity with direct measurement of visceral adiposity may help in explaining why the performance of these indicators differs in men and women of different ethnic background.

In our study the optimal cut points for WC and for WHR were similar among women of different ethnicity. In contrast, WC and WHR optimal cut points were significantly lower in black and Latin-American men than in white men. The differences (7.1 cm and 0.03 units in Blacks and 11.1 cm and 0.04 units in Latin Americans) are unlikely explained by random measurement error or by systematic differences in the site for WC measurements. In fact, Wang, *et al.*45 have shown that measurements of WC at different sites are highly reliable (intraclass correlation coefficient ≥0.99) and that the absolute differences are not larger than 1.6 cm in men and 4.6 cm in women, compared to the method used in NHANES (WC measured immediately above the iliac crest). More important, WC values measured at different sites are almost equally associated with total body fat and trunk fat.45 Although WC and WHR may have been underestimated in Latin Americans, as a consequence of site of measurement, the degree of underestimation was too small to explain the observed difference in the optimal cut points. This is particularly true in men, because the WC cut point was 11.1 cm lower in Latin Americans than in Whites, whereas the expected difference attributable to site of measurement is not larger than 2 cm. A larger amount of visceral adipose tissue adjusted for total fat and age in white than in black men, but not in women, may partly explain why different WC and WHR cut points are needed in white and black men.46

The inclusion of eight health surveys based on random samples from different regions of Latin America and the Caribbean, as well as the inclusion of a representative sample of the US population constitutes one of the major strengths of our study. In this regard, our results may be generalizable not only to ethnic groups in the US, but also to Latin Americans. Importantly, our analysis was based on the contrast of AUCs, an approach that allows for direct comparisons of the accuracy of BMI, WC and WHR, independently of their metrics, and is not affected by the high correlation between these indicators. Moreover, by using multiple imputation we likely decreased the potential selection bias and the loss of power that would have resulted from excluding from the analysis those individuals with missing values in one or more study variables.30 On the other hand, results based on the analysis of individuals without missing values (listwise deletion) were very similar to those obtained using multiple imputation (data not shown).

Using the Framingham equation to predict CHD risk is also a strength of our study, because the accuracy of anthropometric indicators likely varies for different cardiovascular risk factors. In contrast, the Framingham equation summarizes most major risk factors and is widely used for clinical decisions. D'Agostino has shown that the Framingham equation

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accurately predicts CHD risk in whites and Blacks, but may overestimates the absolute risk of CHD in Latin Americans.47 However, the degree of overestimation is reduced by using ethnic-specific mean values for risk factors and should not bias our results, as far as it is independent from the degree of obesity. We also recognize that gathering data from different studies may introduce some systematic error, particularly if different measurement methods have been used. However, risk factors and anthropometric measures followed similar, widely used protocols in all the studies. We recognized the inherent difficulties in the definition of ethnicity and that individual ethnic groups identified in our study are likely heterogeneous in their genetic background as well as on their cultural attitude and environmental exposures.48,49 This is particularly true for the Latin-American group, which includes individuals of European, African and indigenous origins living in different countries. Consequently, our definition of ethnic groups is mostly based on our goal to generate knowledge applicable to the epidemiologic surveillance, planning and delivery of health care in populations in a geographic area.

In summary, our results show that WHR is the anthropometric indicator with the best accuracy to identify individuals at high risk of CHD, whereas BMI is almost uninformative. In addition, our results do not support the use of ethnic-specific cut points for BMI in the whole American population or for WC and WHR in women; however, ethnic-specific cut points for WC and WHR among men seem warranted.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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**Table 1**

Characteristics of the health surveys from the Latin-American Consortium of Studies in Obesity and the National Health and Nutrition Examination Survey

| *Health survey* | *Location* | *Year(s)* | *Sample size* | *Mean age (years)* |
|---|---|---|---|---|
| Encuesta Nacional de Salud12 | Chile[a] | 2003 | 2590 | 51.5 |
| CARMEN13 | Colombia, Bogotá[b] | 2001 | 642 | 44.4 |
| CARMEN4 | Colombia, Bucaramanga[b] | 2001 | 1874 | 43.1 |
| EFRICARD14 | Dominican Republic[c] | 1998 | 5206 | 49.3 |
| ENINBSC-ECNT15 | Perú[a] | 2005 | 3037 | 46.6 |
| PREVENCION16 | Perú, Arequipa[b] | 2004-2006 | 1400 | 51.5 |
| Metabolic syndrome in San Juan17 | Puerto Rico[b] | 2005-2007 | 699 | 52.3 |
| The Zulia CHD risk-factor study18 | Venezuela, Zulia[d] | 1999-2001 | 3527 | 47.8 |
| NHANES III19 | United States[a] | 1988-1994 | 10 878 | 47.8 |
| NHANES 1999-200420 | United States[a] | 1999-2004 | 9086 | 48.4 |

Abbreviation: CHD, coronary heart disease.

[a]National survey.

[b]City survey.

[c]National survey urban population.

[d]State survey.

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**Table 2**

Characteristics of study participants by ethnicity

| ***Characteristic (mean)*** | ***Whites* (n=*4499*)** | ***Black* (n=*1986*)** | ***Hispanics* (n=*2601*)** | ***Latin Americans* (n=*18976*)** |
|---|---|---|---|---|
| % Men (*n*) | 49.4 (2290) | 44.9 (968) | 49.8 (1285) | 38.5 (7301) |
| Age (years) | 49.1 | 46.8 | 45.4 | 48.4 |
| *Body mass index (kg/m$^2$)* | | | | |
| Men | 28.5 | 28.2 | 28.1 | 26.2 |
| Women | 28.2 | 31.8 | 29.4 | 27.2 |
| *Waist circumference (cm)* | | | | |
| Men | 102.4 | 97.8 | 98.2 | 93.2 |
| Women | 93.8 | 100.1 | 94.6 | 89.2 |
| *Waist-to-hip ratio* [a] | | | | |
| Men | 0.97 | 0.94 | 0.98 | 0.94 |
| Women | 0.87 | 0.89 | 0.89 | 0.85 |
| Blood pressure (mm Hg) | | | | |
| Systolic | 123.3 | 128.9 | 123.3 | 126.0 |
| Diastolic | 73.7 | 75.9 | 73.3 | 78.3 |
| Total cholesterol (mg per 100 ml) | 208.1 | 200.8 | 206.4 | 185.9 |
| HDL cholesterol (mg per 100 ml) | 52.4 | 54.7 | 48.5 | 44.8 |
| Diabetes mellitus (%) | 7.0 | 12.9 | 11.2 | 8.0 |
| Current smokers (%) | 22.0 | 25.9 | 16.8 | 21.0 |
| High risk of CHD (%)[b] | 12.2 | 9.7 | 9.3 | 13.3 |

Abbreviations: CHD, coronary heart disease; HDL, high-density lipoprotein.

[a]Based on data from NHANES III for the United States population.

[b]High risk of coronary heart disease defined as a 10-year risk ≥20% based on the Framingham equation.

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**Table 3**

Area under the ROC curve of each anthropometric indicator by ethnicity and gender

| | ***Whites* (n=*8956*)** | ***Blacks* (n=*5205*)** | ***Hispanics* (n=*5803*)** | ***Latin Americans* (n=*18 976*)** |
|---|---|---|---|---|
| *Body mass index* | | | | |
| Men | 0.57 (0.55, 0.58)* | 0.56 (0.53, 0.58)* | 0.53 (0.51, 0.56) | 0.55 (0.54, 0.57)* |
| Women | 0.70 (0.66, 0.74) | 0.61 (0.56, 0.66) | 0.56 (0.52, 0.61) | 0.60 (0.58, 0.62) |
| All | 0.59 (0.57, 0.60) | 0.50 (0.48, 0.52)† | 0.51 (0.49, 0.53)† | 0.53 (0.52, 0.54)† |
| *Waist circumference* | | | | |
| Men | 0.64 (0.62, 0.65)* | 0.64 (0.62, 0.67) | 0.63 (0.61, 0.65) | 0.62 (0.61, 0.64)* |
| Women | 0.76 (0.72, 0.79) | 0.68 (0.64, 0.72) | 0.65 (0.61, 0.69) | 0.65 (0.62, 0.68) |
| All | 0.70 (0.69, 0.72)‡ | 0.62 (0.59, 0.64)†‡ | 0.65 (0.63, 0.67)†‡ | 0.65 (0.64, 0.67)†‡ |
| *Waist-to-hip ratio* | | | | |
| Men | 0.72 (0.70, 0.74)* | 0.77 (0.75, 0.80) | 0.73 (0.70, 0.75) | 0.65 (0.63, 0.68)* |
| Women | 0.79 (0.75, 0.83) | 0.75 (0.70, 0.80) | 0.76 (0.71, 0.81) | 0.69 (0.65, 0.72) |
| All | 0.82 (0.81, 0.84)‡ | 0.80 (0.78, 0.82)‡ | 0.79 (0.77, 0.81)†‡ | 0.75 (0.73, 0.77)†‡ |

*$P<0.05$ for gender within ethnic group

†$P<0.05$ for comparisons between Blacks, Hispanics and Latin Americans and Whites (reference group) for each anthro pometric indicator (all individuals were considered)

‡$P<0.05$ for comparisons between waist circumference and body mass index, and waist-to-hip ratio and body mass index within ethnic group (all individuals were considered).

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**Table 4**

Sensitivity of each anthropometric indicator at a fixed specificity of 80% by ethnicity and gender

| | ***Whites* (n=*8956*)** | ***Blacks* (n=*5205*)** | ***Hispanics* (n=*5803*)** | ***Latin Americans* (n=*18 976*)** |
|---|---|---|---|---|
| *Body mass index* | | | | |
| Men | 0.27 (0.24, 0.30)* | 0.26 (0.22, 0.31) | 0.24 (0.20, 0.28) | 0.26 (0.23, 0.28)* |
| Women | 0.45 (0.37, 0.54) | 0.30 (0.21, 0.38) | 0.23 (0.17, 0.30) | 0.31 (0.27, 0.35) |
| All | 0.25 (0.23, 0.27)† | 0.15 (0.12, 0.18)† | 0.18 (0.15, 0.20)† | 0.21 (0.19, 0.23)† |
| *Waist circumference* | | | | |
| Men | 0.34 (0.31, 0.37)* | 0.36 (0.31, 0.41) | 0.33 (0.29, 0.37) | 0.32 (0.29, 0.36)* |
| Women | 0.53 (0.44, 0.61) | 0.39 (0.30, 0.48) | 0.36 (0.28, 0.45) | 0.38 (0.33, 0.44) |
| All | 0.41 (0.38, 0.44)‡ | 0.29 (0.25, 0.32)†‡ | 0.35 (0.31, 0.38)†‡ | 0.36 (0.33, 0.38)†‡ |
| *Waist-to-hip ratio* | | | | |
| Men | 0.49 (0.43, 0.54)* | 0.55 (0.49, 0.62) | 0.49 (0.42, 0.56) | 0.39 (0.35, 0.43) |
| Women | 0.61 (0.51, 0.71) | 0.53 (0.43, 0.63) | 0.54 (0.43, 0.64) | 0.43 (0.37, 0.49) |
| All | 0.67 (0.63, 0.70)‡ | 0.64 (0.59, 0.69)‡ | 0.62 (0.58, 0.67)‡ | 0.56 (0.53, 0.70)†‡ |

*$P<0.05$ for gender within ethnic group

†$P<0.05$ for comparisons between Blacks, Hispanics and Latin Americans and Whites (reference group) for each anthropometric indicator (all individuals were considered)

‡$P<0.05$ for comparisons between waist circumference and body mass index, and waist-to-hip ratio and body mass index within ethnic group (all individuals were considered).

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**Table 5**

Optimal cut points for anthropometric indicators of obesity to identify individuals at high risk of coronary heart disease by ethnicity and gender

| *Ethnicity* | *Cut point (95% confidence interval)* | | |
|---|---|---|---|
| | ***Body mass index (kg/m$^2$)*** | ***Waist circumference (cm)*** | ***Waist-to-hip ratio*** |
| *Women* | | | |
| White | 27.4 (23.4, 31.4) | 96.8 (92.1, 101.5) | 0.89 (0.86, 0.93) |
| Black | 28.3 (24.2, 32.1) | 95.5 (89.5, 101.4) | 0.93 (0.90, 0.96) |
| Hispanic | 27.8 (24.9, 30.7) | 93.5 (91.6, 95.4) | 0.92 (0.90, 0.95) |
| Latin American | 27.9 (24.4, 31.3) | 93.0 (87.0, 99.0) | 0.87 (0.84, 0.90) |
| All[a] | 27.8 (26.1, 29.6) | 94.0 (92.4, 95.6) | 0.91 (0.88, 0.93) |
| *Men* | | | |
| White | 27.9 (26.4, 29.4) | 102.1 (98.4, 105.8) † | 0.98 (0.96, 1.00) † |
| Black | 26.2 (25.5, 26.9) | 95.0 (91.2, 98.8) * | 0.95 (0.94, 0.97) * |
| Hispanic | 25.4 (22.0, 28.8) | 99.2 (95.4, 103.0) † | 0.99 (0.97, 1.01) † |
| Latin American | 26.4 (23.8, 28.9) | 91.0 (87.3, 94.7) * | 0.94 (0.93, 0.95) *† |
| All[a] | 26.6 (25.7, 27.6) | 96.8 (92.0, 101.6) | 0.96 (0.94, 0.98) |

* *P* value <0.05 for comparisons between Blacks, Hispanics and Latin Americans vs Whites (reference group)

† *P* value <0.05 for comparisons between men and women.

[a] Pooled estimates and 95% confidence intervals based on random effects meta-analysis.

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**Table 6**

Sensitivity and specificity of the cut points currently recommended to define obesity and optimal cut points derived from our study

| ***Indicator*** [a] | | ***Cut points*** | |
|---|---|---|---|
| | | ***Currently recommended*** [a] | ***Study derived*** |
| *Body mass index (kg/m²)* | *Women/men* | *30/30* | *28/27* |
| Women | Sensitivity | 46.5 (42.3, 50.9) | 62.6 (58.5, 66.8) |
| | Specificity | 68.9 (68.0, 69.8) | 57.1 (56.2, 58.1) |
| Men | Sensitivity | 27.9 (26.2, 29.6) | 51.7 (49.8, 53.6) |
| | Specificity | 78.4 (77.4, 79.5) | 56.2 (55.0, 57.5) |
| *Waist circumference (cm)* | *Women/men* | *88/102* | *94/97* |
| Women | Sensitivity | 83.2 (79.7, 86.7) | 70.9 (66.7, 75.1) |
| | Specificity | 41.5 (40.4, 42.5) | 58.1 (57.1, 59.2) |
| Men | Sensitivity | 45.2 (43.2, 47.2) | 62.3 (60.4, 64.3) |
| | Specificity | 73.0 (71.8, 74.2) | 59.5 (58.2, 60.9) |
| *Waist-to-hip ratio* | *Women/men* | *0.90/1.00* | *0.91/0.96* |
| Women | Sensitivity | 67.6 (62.5, 72.7) | 61.5 (56.2, 66.8) |
| | Specificity | 65.5 (64.2, 66.8) | 70.1 (68.8, 71.3) |
| Men | Sensitivity | 50.5 (47.8, 53.2) | 73.5 (71.1, 75.9) |
| | Specificity | 78.6 (77.1, 80.2) | 58.3 (56.5, 60.2) |

[a]Cut points recommended by the WHO35 for body mass index and waist circumference. Sex-specific cut points for waist-to-hip ratio from Bray.36