

ORIGINAL ARTICLE

LMS tables for waist circumference and waist–height ratio in Colombian adults: analysis of nationwide data 2010

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BACKGROUND/OBJECTIVES: Indices predictive of central obesity include waist circumference (WC) and waist-to-height ratio (WHtR). These data are lacking for Colombian adults. This study aims at establishing smoothed centile charts and LMS tables for WC and WHtR; appropriate cutoffs were selected using receiver-operating characteristic analysis based on data from the representative sample.

SUBJECTS/METHODS: We used data from the cross-sectional, national representative nutrition survey (ENSIN, 2010). A total of 83 220 participants (aged 20–64) were enrolled. Weight, height, body mass index (BMI), WC and WHtR were measured and percentiles calculated using the LMS method (L (curve Box-Cox), M (curve median), and S (curve coefficient of variation)). Receiver operating characteristic curve analyses were used to evaluate the optimal cutoff point of WC and WHtR for overweight and obesity based on WHO definitions.

RESULTS: Reference values for WC and WHtR are presented. Mean WC and WHtR increased with age for both genders. We found a strong positive correlation between WC and BMI ($r=0.847$, $P < 0.01$) and WHtR and BMI ($r=0.878$, $P < 0.01$). In obese men, the cutoff point value is 96.6 cm for the WC. In women, the cutoff point value is 91.0 cm for the WC. Receiver operating characteristic curve for WHtR was also obtained and the cutoff point value of 0.579 in men, and in women the cutoff point value was 0.587. A high sensitivity and specificity were obtained.

CONCLUSIONS: This study presents first reference values of WC and WHtR for Colombians aged 20–64. Through LMS tables for adults, we hope to provide quantitative tools to study obesity and its complications.

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INTRODUCTION

The prevalence of overweight and obesity has become a public health problem worldwide.¹ Substantial evidence indicates that increased body weight (BW) and body fat distribution have been associated with a higher frequency of adverse health consequences including hypertension, cardiovascular disease, metabolic disorders, osteoarthritis, gallbladder stone disease, asthma, as well as multiple malignancies.^{2–4} International organisations and previous epidemiological cross-sectional studies have suggested that individuals with a large accumulation of body fat in the abdominal region are at greater risk of development of the metabolic syndrome.^{3,5–9} To estimate the magnitude of this problem, direct indicators were used to assess various anthropometric indicators, such as body mass index (BMI), waist circumference (WC) and waist-to-height ratio (WHtR).^{8,10,11} All these indicators are simple, inexpensive, non-invasive and validated methods to apply in clinical practice and epidemiological studies.^{10,12,13}

WC has been accepted by international organisations such as the International Diabetes Federation as a diagnostic criteria of metabolic complications.^{3,14} In addition to the WC, the WHtR (waist (cm)/height (Ht, cm); also called the index of central obesity) has been suggested as a potentially useful index to determine

abdominal fat deposition.^{3,15–17} Recently, Ashwell's¹⁰ report in a robust meta-analysis, including data on more than 300 000 individuals from diverse populations across the world, confirms previous claims from smaller and less robust analyses that measures of abdominal obesity, especially WHtR, provide a superior tool for discriminating obesity-related cardiometabolic risk compared with BMI. In addition, in 'within studies' comparison, these authors showed that WHtR was significantly superior to WC for diabetes, dyslipidaemia, hypertension and cardiovascular disease.

Given the risk of over nutrition in developing countries, it is necessary to measure its prevalence in vulnerable populations such as Latin-American people to identify high-risk groups and develop preventive interventions.¹⁸ Currently, there are few global reports on the prevalence of overweight and obesity, in particular for low-to-middle income countries (LMICs) experiencing rapid nutrition transitions such as Latin America or Africa.^{19,20} Low-to-middle income countries including Colombia are an environment to assess body composition because the prevalence of both underweight and overweight individuals is relatively high; furthermore, an obesity gradient that includes developing countries from even the poorest households has been reported.¹⁹ In addition, it is likely that ethnicity and environmental differences influence body proportions, indicating the usefulness

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of national references to control for variations between populations. Cutoff values and percentiles for WC and WHtR are available for adults in several countries.^{21–26} However, to the best of our knowledge, anthropometric indicators (WC and WHtR) that could help identify risk groups and offer information to better design interventions have not been investigated in a nationally representative sample in the Americas.

The aims of this study were to establish a Colombian smoothed centile chart and LMS tables for WC and WHtR based on data from the Colombian national nutrition survey.

MATERIALS AND METHODS

Design

The Colombian National Nutrition Survey (ENSIN, 2010) was carried out together with the National Demographic and Health Survey by Asociación Pro-bienestar de la Familia Colombiana (PROFAMILIA), a nonprofit organisation focusing on reproductive health.²⁷ Details of the survey have been published elsewhere.²⁷ In brief, participants were selected to represent 99% of the country's population using a multistage stratified sampling scheme. Subsamples were randomly drawn to estimate departmental, subregional, regional and/or national-level estimates of specific nutrition problems among individuals 0–64 years of age.²⁸ All municipalities from the thirty-two departments in the country were grouped into a strata based on similar geographic and sociodemographic characteristics. The survey included 50 670 households, representing 4987 clusters from 258 strata.²⁷ The first author applied to the PROFAMILIA-ENSIN and obtained permission to use the publicly available data for research and teaching learning purpose. Further details can be obtained from the website of PROFAMILIA-ENSIN (<http://www.icbf.gov.co/portal/page/portal/PortalICBF/Bienestar/ENSIN1>).

Participants

The present cross-sectional study included 83 220 participants 20–64 years of age (mean age 40.9 ± 16.7). A total of 108 916 of 25 696 (76.9%) subjects were omitted, because of missing values for WC and/or Ht (36 264 men/46 956 (56.4%) women). The study was conducted according to the guidelines laid down in the Declaration of Helsinki. All participants provided written informed consent and the Research Ethics Review Board at the Colombian Institute of Family Welfare approved the survey protocol. A comprehensive verbal description of the nature and purpose of the study and its experimental risks was given to all participants and provided written informed consent before entering the study. The Ethical Committee of the PROFAMILIA provided ethical approval before data collection. To conduct the present analysis using the ENSIN 2010 database, the Manuela Beltrán University Research Ethics exempted the project (Resolución 8430 de 1993; Ministerio de Salud de Colombia).

Data sources

Anthropometric measurements were obtained in all household members with the use of standardised techniques and calibrated instruments. Ht was measured with the use of a stadiometer (Diseños Flores S.R. Ltda, Bogotá, Colombia) to the nearest millimetre. BW was measured on SECA 872 scales to the nearest 100 g. BMI was calculated as weight (kg)/height² (m²). WC was measured twice using inextensible anthropometric tape with the subjects standing erect and relaxed with arms at the sides and feet positioned close together. WC was measured midway between the lowest border of rib cage and the upper border of iliac crest, at the end of normal expiration. WHtR was expressed as the ratio of WC (in cm) to Ht (in cm). For all measurements, the tape was positioned at a level parallel to the floor. Overweight and obesity were defined as having a BMI above the age- and sex-specific thresholds of the WHO.⁶ According to this definition, the group of subjects with overweight (the equivalent of BMI > 25 kg/m²) also contains those who are obese (the equivalent of BMI > 30 kg/m²).

Data analysis

Anthropometric characteristics from the study sample are presented as the mean with standard deviation (s.d.). Normality for selected variables was verified using histograms and Q–Q plots. Data were then split by sex and a one-way ANOVA with *post hoc* tests (Tukey) was used to identify differences between age groups within sexes. Smoothed age- and

gender-specific table and graph percentiles were constructed for WC and WHtR via a penalised maximum likelihood with the following abbreviations: (1) M (median), (2) L (Box–Cox transformation) and (3) S (coefficient of variation).²⁹ The appropriate number of degrees of freedom was selected on the basis of the deviance, Q-tests and worm plots, following the suggestions of Royston and Wright.³⁰ The 3rd, 10th, 25th, 50th, 75th, 90th and 97th smoothing centiles were chosen as age- and gender-specific reference values. The associations between WC, WHtR and BMI were tested by means of Pearson's correlation coefficients. The relation between WC, WHtR and overweight/obesity as defined by the WHO was investigated with 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 formula: $(1 - \text{sensitivity})^2 + (1 - \text{specificity})^2$.² The positive likelihood ratio LR (+) and the negative likelihood ratio LR (–) were also determined. Reference curves were fitted using LMS Chartmaker version 2.3 (Medical Research Council, London, UK). Descriptive statistics were calculated with SPSS Rel.21.0 (SPSS Inc., Chicago, IL, USA). Statistical significance was set at $P < 0.05$.

RESULTS

Descriptive statistics for weight, Ht, BMI, WC and WHtR by age group are presented in Table 1. The corresponding percentiles are listed in Table 2 (WC) and Table 3 (WHtR). The corresponding smoothed percentile curves are listed in Figure 1 (WC) and Figure 2 (WHtR). Mean BMI was highly comparable in both sexes, and the prevalence of overweight was 35.8% (95% confidence of interval (CI): 35.4–36.3%) in women and 36.2% (95% CI: 35.7–36.7%) in men and that of obesity was 21.9% (95% CI: 21.6–22.3%) and 12.8% (95% CI: 12.5–13.2%), respectively. Mean WC and WHtR increased with age in both sexes, but men had statistically significantly higher values for all ages ($P < 0.0001$). In both sexes, we found a strong positive correlation between WC and BMI ($r = 0.847$, $P < 0.01$) and WHtR and BMI ($r = 0.878$, $P < 0.01$).

Receiver operating characteristic analysis showed that both WC and WHtR had a high discriminating power to detect WHO overweight and obesity (Figures 3 and 4).

In the overweight category in men, the cutoff point value of 87.6 cm for the WC provided a sensitivity of 87.6%, a LR (+) value of 7.01, specificity of 87.5% and LR (–) value of 0.14. In women, the cutoff point value of 84.0 cm for the WC provided a sensitivity of 84.0%, a LR (+) value of 7.30, specificity of 88.5% and LR (–) value of 0.18.

In the obesity category in men, the cutoff point value of 96.6 cm for the WC provided a sensitivity of 92.9%, a LR (+) value of 7.31, specificity of 87.3% and LR (–) value of 0.08. In women, the cutoff point value of 91.0 cm for the WC provided a sensitivity of 89.2%, a LR (+) value of 6.42, specificity of 86.1% and LR (–) value of 0.13 (Figure 3 and Table 4).

ROC curve for WHtR was also obtained (Figure 4 and Table 4), and the cutoff point value of 0.521 was used. In the overweight category considering this cutoff point, in men sensitivity was 88.8%, LR (+) value of 5.80, specificity 84.7% and LR (–) 0.13. In women, the cutoff point value was 0.536, sensitivity 85.8%, LR (+) value of 6.01, specificity 85.8% and LR (–) 0.17. In the obesity category in men, the cutoff point value of 0.579 was used. The sensitivity was 90.7%, LR (+) value of 6.98, specificity 87.0% and LR (–) 0.11. In women, the cutoff point value was 0.587 with sensitivity 84.5%, LR (+) value of 5.80, specificity 84.5% and LR (–) 0.12 (Figure 3 and Table 4).

DISCUSSION

This paper presents the first sex- and age-specific WC and WHtR percentiles for Colombian adults, 20–64 years of age. In the case of the male subjects, the mean BW tended to increase until the age of 40, after which it steadily decreased. This contrasted with the findings for women, whose mean BW increased for all of the ages studied. This coincided with previous research.^{31,32} In regard to Ht,

Table 1. Mean values (s.d.) for BW, Ht, BMI, WC and WHtR for Colombian adults aged 18–64 years

Sex	n	BW (kg)	Ht (cm)	BMI (kg/m ²)	WC (cm)	WHtR
<i>Men</i>						
20–24.9	5794	66.5 (11.8)**	168.8 (7.0)**	23.3 (3.6)**	80.1 (9.3)**	0.475 (0.055)**
25–29.9	5127	70.6 (13.4)**	168.4 (7.0)**	24.8 (4.1)*	85.0 (11.0)**	0.505 (0.064)**
30–34.9	4675	72.5 (13.4)**	168.1 (7.1)**	25.7 (4.9)**	88.0 (10.9)**	0.524 (0.065)**
35–39.9	4243	72.8 (13.2)**	167.4 (7.0)**	25.9 (4.2)**	89.6 (11.0)**	0.536 (0.065)**
40–44.9	4364	73.4 (13.1)**	167.3 (6.9)**	26.2 (4.3)**	91.2 (11.0)**	0.545 (0.065)**
45–49.9	3995	72.7 (13.3)**	166.6 (6.9)**	26.2 (4.2)**	91.9 (11.5)**	0.552 (0.069)**
50–54.9	3214	71.7 (13.3)**	165.7 (6.9)**	26.0 (4.2)**	92.5 (11.7)**	0.558 (0.069)**
55–59.9	2658	71.0 (13.1)**	165.1 (7.0)**	26.0 (4.2)**	93.2 (11.9)**	0.565 (0.073)**
60–64.9	2194	69.4 (12.7)**	164.3 (6.9)**	25.7 (4.0)**	93.0 (11.6)**	0.567 (0.068)**
Total	36 264	71.1 (13.2)**	167.3 (7.1)**	25.4 (4.3)**	88.4 (11.8)**	0.529 (0.072)**
<i>Women</i>						
20.0–24.9	6703	58.0 (11.2)	156.4 (6.2)	23.7 (4.3)	77.4 (10.5)	0.496 (0.068)
25–29.9	6476	61.1 (12.1)	156.1 (6.3)	25.1 (4.6)	81.2 (11.1)	0.521 (0.072)
30–34.9	6010	63.2 (12.5)	155.3 (6.3)	26.2 (4.8)	84.1 (11.4)	0.542 (0.074)
35–39.9	5742	64.4 (12.6)	155.1 (6.2)	26.8 (4.9)	85.7 (11.1)	0.553 (0.073)
40–44.9	5900	65.4 (13.0)	154.7 (6.4)	27.3 (5.1)	87.3 (11.4)	0.565 (0.075)
45–49.9	5417	66.1 (12.6)	154.2 (6.2)	27.8 (5.0)	88.9 (11.1)	0.577 (0.074)
50–54.9	4544	66.3 (12.9)	153.4 (6.3)	28.2 (5.1)	90.8 (11.7)	0.593 (0.078)
55–59.9	3462	65.7 (13.0)	152.5 (6.4)	28.2 (5.1)	91.8 (12.0)	0.603 (0.079)
60–64.9	2702	64.2 (13.2)	151.5 (6.3)	28.0 (5.3)	91.8 (12.2)	0.607 (0.082)
Total	46 956	63.5 (12.8)	154.7 (6.4)	26.5 (5.1)	85.6 (12.2)	0.554 (0.082)

Significant difference between men and women within the same age group: * $P < 0.01$; ** $P < 0.0001$.

Table 2. Smoothed age- and sex-specific percentile of WC (cm) for Colombian adults aged 18–64 years

	n	M	s.d.	P ₃	P ₁₀	P ₂₅	P ₅₀	P ₇₅	P ₉₀	P ₉₇
<i>Men</i>										
20–24.9	5794	80.1	9.3	67.0	70.3	73.7	78.2	84.5	93.0	102.0
25–29.9	5127	85.0	11.0	69.2	72.8	77.0	83.5	91.5	99.5	107.5
30–34.9	4675	88.0	10.9	71.0	75.0	80.0	86.9	94.7	102.4	111.0
35–39.9	4243	89.6	11.0	71.9	76.6	81.5	88.8	96.2	103.6	112.0
40–44.9	4364	91.2	11.0	72.6	77.4	83.4	90.9	97.9	105.4	113.3
45–49.9	3995	91.9	11.5	72.7	77.5	83.5	91.5	98.8	106.4	114.7
50–54.9	3214	92.5	11.7	72.4	77.6	84.2	92.4	99.8	107.1	115.6
55–59.9	2658	93.2	11.9	73.2	78.0	85.0	93.1	100.5	107.8	116.1
60–64.9	2194	93.0	11.6	73.0	77.8	84.4	93.0	100.9	108.0	114.6
Total	36 264	88.4	11.8	70.0	74.1	79.4	87.4	96.0	103.9	112.2
<i>Women</i>										
20.0–24.9	6703	77.4	10.5	62.8	66.0	70.2	75.8	82.5	90.7	100.5
25–29.9	6476	81.2	11.1	64.8	68.8	73.5	79.5	87.2	95.8	104.7
30–34.9	6010	84.1	11.4	66.5	71.2	76.2	82.8	90.1	98.7	108.0
35–39.9	5742	85.7	11.1	67.8	72.5	78.1	84.5	92.2	100.2	109.5
40–44.9	5900	87.3	11.4	68.5	73.9	79.5	86.5	94.1	101.5	111.3
45–49.9	5417	88.9	11.1	70.0	75.4	81.2	88.2	95.8	103.2	112.0
50–54.9	4544	90.8	11.7	70.8	76.6	82.8	90.1	98.2	105.9	113.9
55–59.9	3462	91.8	12.0	70.6	77.5	83.7	91.4	99.1	106.6	114.9
60–64.9	2702	91.8	12.2	69.8	76.5	83.7	91.3	99.0	107.1	115.5
Total	46 956	85.6	12.2	65.9	70.9	76.8	84.5	93.1	101.4	110.6

Abbreviations: M, mean; s.d., standard deviation; P, percentile.

the values for both men and women tended to decrease as they became older. We agree with Minaker,³³ who states that this loss of Ht is most likely due to changes related to ageing. Similar results were obtained in other studies.^{34,35}

The mean BMI values for both men and women steadily increased until roughly the age of 60. However, after 60, the values for men decreased, whereas those for women remained at the same level with little variation. Our results differ from Zaher *et al.*³⁶ who studied 1833 adults in Malaysia and reported

lower mean BMI values for women and higher BMI values for men.

As reflected in our results, the prevalence of overweight in both men and women was higher than the results obtained in other research such as Ouyang *et al.*,³⁷ who reported that 31.3% of the adult population in China was overweight and 2% was obese. This could be explained by the fact that the sample populations in the two studies belong to very different cultural and nutritional contexts.

Our results for the WC and WHtR parameters agreed with those obtained in previous research.^{10,26,38} In our study, values for both genders tended to increase as the subjects grew older, although

this increase was more pronounced in men. Although our data are not longitudinal (thus making it impossible to confirm a progressive increase in waist perimeter with age), the literature

Table 3. Smoothed age- and sex-specific percentile values of WHtR for Colombian adults aged 18–64 years

	n	M	s.d.	P ₃	P ₁₀	P ₂₅	P ₅₀	P ₇₅	P ₉₀	P ₉₇
<i>Men</i>										
20–24.9	5794	0.475	0.055	0.394	0.414	0.436	0.466	0.503	0.548	0.598
25–29.9	5127	0.505	0.064	0.408	0.432	0.460	0.498	0.545	0.585	0.635
30–34.9	4675	0.524	0.065	0.420	0.447	0.479	0.518	0.562	0.606	0.654
35–39.9	4243	0.536	0.065	0.429	0.457	0.489	0.531	0.575	0.617	0.664
40–44.9	4364	0.545	0.065	0.434	0.465	0.501	0.544	0.585	0.628	0.675
45–49.9	3995	0.552	0.069	0.435	0.468	0.506	0.548	0.594	0.637	0.685
50–54.9	3214	0.558	0.069	0.436	0.469	0.510	0.558	0.601	0.647	0.698
55–59.9	2658	0.565	0.073	0.443	0.478	0.515	0.564	0.607	0.653	0.697
60–64.9	2194	0.567	0.068	0.442	0.477	0.518	0.568	0.612	0.654	0.696
Total	36 264	0.529	0.072	0.414	0.441	0.476	0.525	0.575	0.621	0.670
<i>Women</i>										
20–24.9	6703	0.496	0.068	0.397	0.421	0.448	0.486	0.531	0.584	0.643
25–29.9	6476	0.521	0.072	0.412	0.439	0.470	0.511	0.563	0.614	0.671
30–34.9	6010	0.542	0.074	0.427	0.456	0.491	0.534	0.585	0.637	0.696
35–39.9	5742	0.553	0.073	0.435	0.466	0.503	0.547	0.595	0.649	0.706
40–44.9	5900	0.565	0.075	0.440	0.476	0.514	0.560	0.609	0.658	0.721
45–49.9	5417	0.577	0.074	0.448	0.489	0.527	0.573	0.623	0.672	0.727
50–54.9	4544	0.593	0.078	0.457	0.498	0.539	0.589	0.641	0.693	0.749
55–59.9	3462	0.603	0.079	0.463	0.507	0.551	0.599	0.651	0.699	0.757
60–64.9	2702	0.607	0.082	0.462	0.504	0.554	0.603	0.656	0.708	0.763
Total	46 956	0.554	0.082	0.421	0.455	0.495	0.547	0.605	0.660	0.722

Abbreviations: M, mean; s.d., standard deviation; P, percentile.

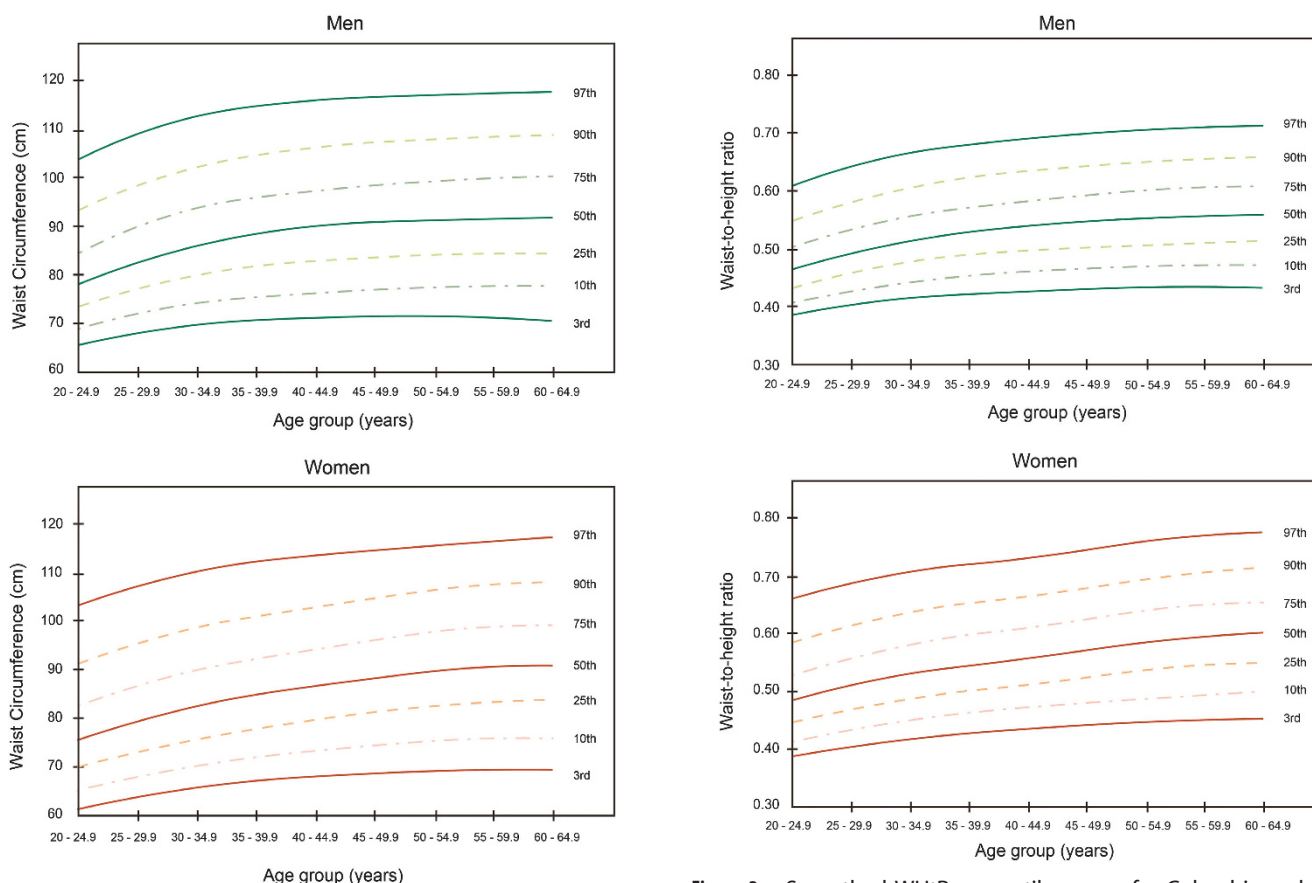


Figure 1. Smoothed WC (in cm) percentile curves for Colombian adults.

Figure 2. Smoothed WHtR percentile curves for Colombian adults.

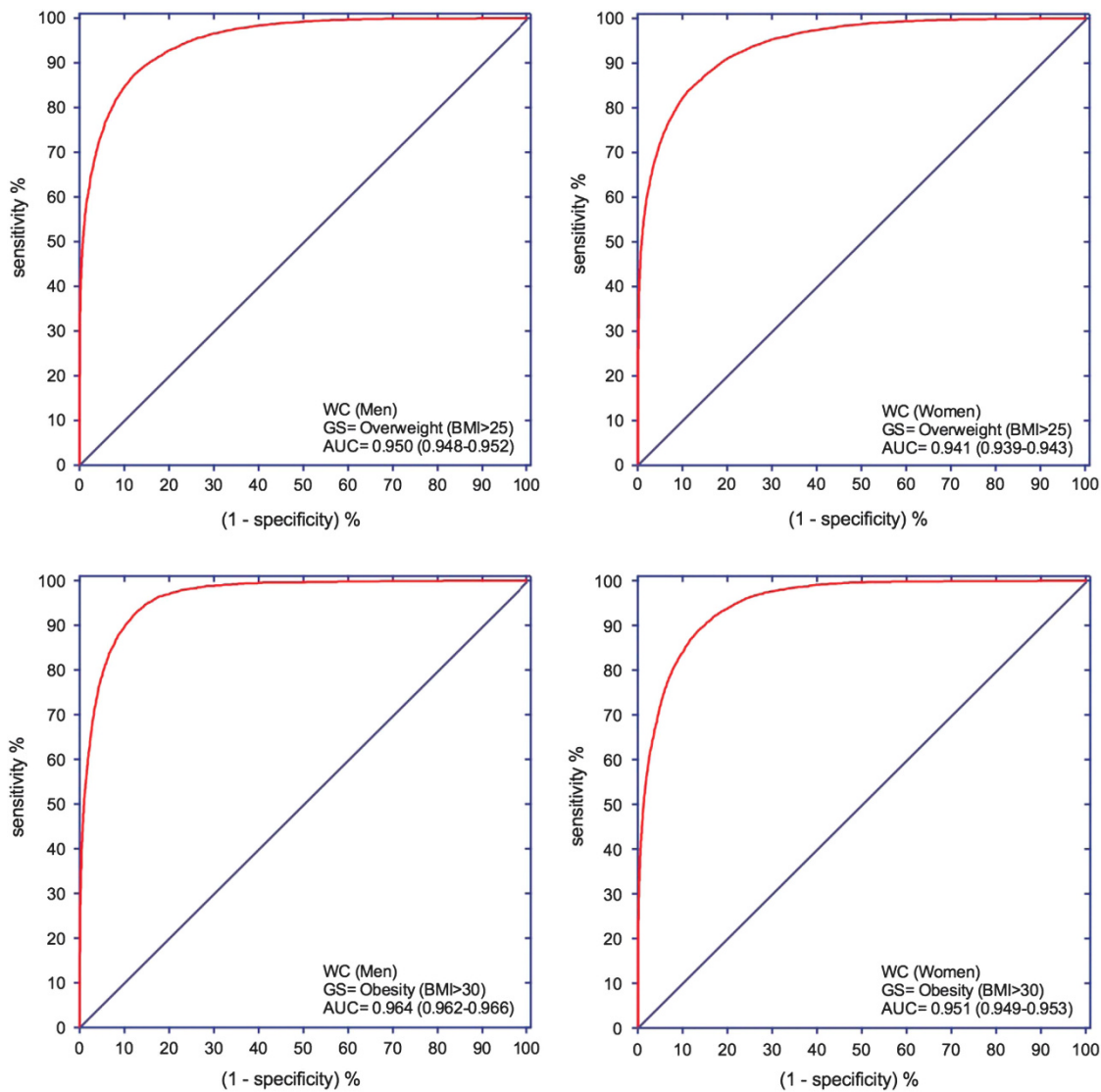


Figure 3. ROC curve of the WC to detect overweight (up) or obesity (down) according to the WHO criteria for Colombian adults. GS, gold standard; AUC, area under the curve (95% CI).

provides ample evidence that age modifies the pattern of subcutaneous fat distribution. As people grow older, fat tends to move from the periphery and to accumulate in the trunk region, which increases the risk of cardiovascular disease.^{39,40} Furthermore, in consonance with Balkau *et al.*⁴¹ in their study of 168 000 adult patients in 63 countries, a positive correlation between WC and BMI values was found for both sexes. Nevertheless, despite the strong correlation observed between WC and BMI values,⁴² it would be helpful to know that the WC values considered normal for each BMI level. Corrective measures could then be applied to those patients with anomalous WC values and thus reducing their risk of cardiometabolic disease.

The results of our study also showed a positive correlation between WHtR and BMI values for both gender groups. This coincides with the results of previous studies^{43–45} in which the WHtR is described as a more accurate indicator than the WHtR for the prediction of cardiometabolic risk in adults of both sexes.

Regarding WC percentiles, the 50th percentile showed higher values for men than for women. These gender-related differences were less pronounced for the 97th percentile. Once again, our results point to sexual dimorphism in regard to the body composition of both sexes.⁴⁶ The WHtR results obtained show

marked differences for both men and women in the ages studied. Higher values were obtained in all percentiles for women than for men, which coincides with the results of previous research.^{47,48}

The ROC shows that both WC and WHtR parameters had a high level of discriminating power when it came to detecting overweight and obesity in the adult population studied. In the male overweight category, we obtained an optimal cutoff value of 87.6 cm, which was higher than the 83 cm reported by Zaher *et al.*³⁶ for Asian men. In contrast, in regard to women, our optimal cutoff value was 84 cm, which is similar to the cutoff value of 83 cm in Zaher *et al.*³⁶ for Asian women. However, it is somewhat lower than the cutoff specified by the WHO⁴⁹ for Caucasian women.

Regarding WC, in the category of male obesity, the optimal cutoff value was 96.6 cm, which was considerably higher than the 89.05 cm reported by Liu *et al.*³⁴ for the male Chinese population. As for the WC results for female obesity, the cutoff was 91.0 cm, which is very similar to the value of 90.90 cm reported by Liu *et al.*³⁴ Other studies such as Miyawaki *et al.*⁵⁰ of Japanese adults obtained optimal WC cutoff values of 86 cm for men and 77 cm for women, which were much lower than the ones obtained in our

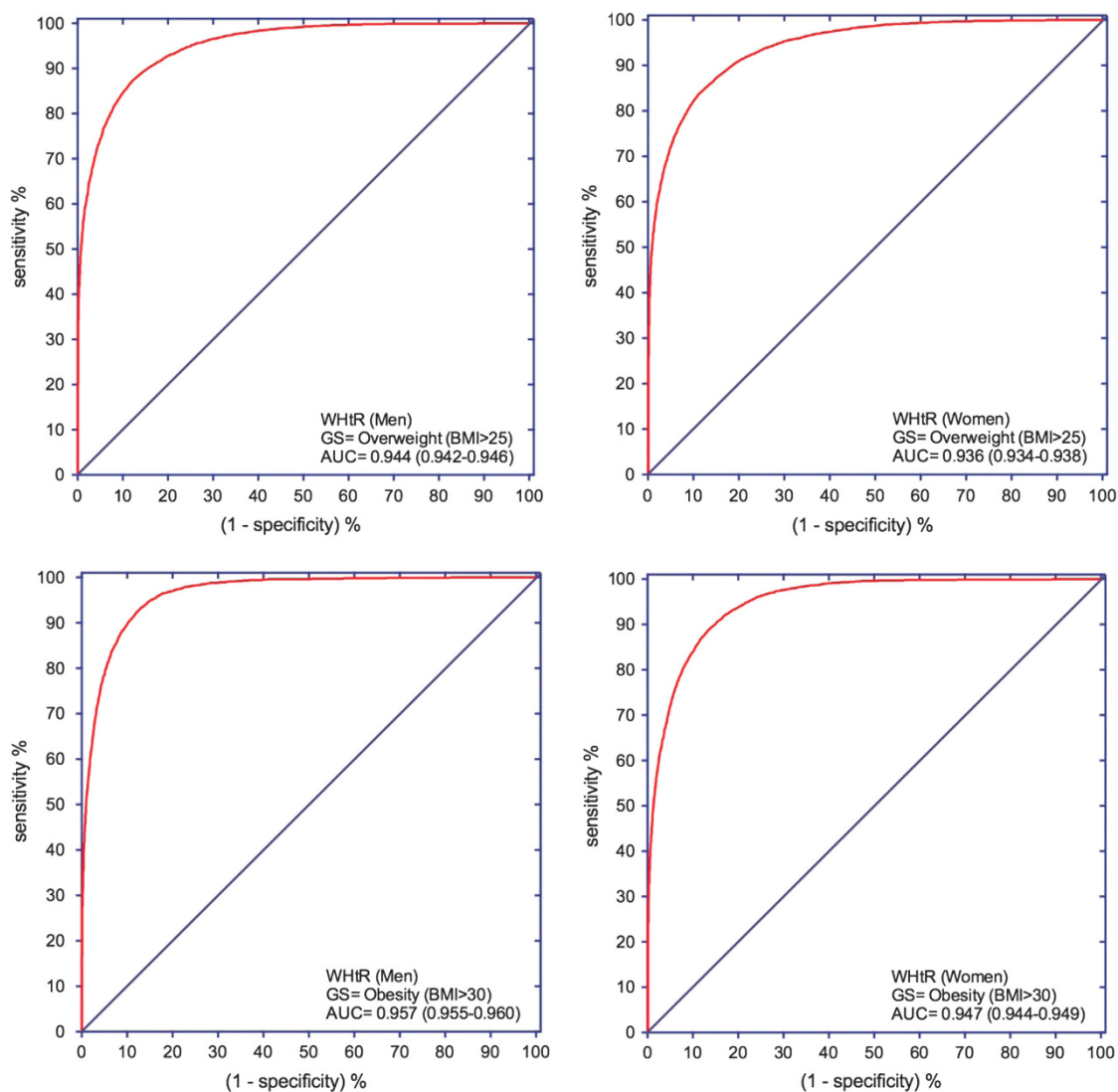


Figure 4. ROC curve of the WHtC to detect overweight (up) or obesity (down) according to the WHO criteria for Colombian adults. GS, gold standard; AUC, area under the curve (95% CI).

Table 4. Area under the AUC for WC and WHtR indices

	WC				WHtC			
	Overweight (BMI > 25 kg/m ²)		Obesity (BMI > 30 kg/m ²)		Overweight (BMI > 25 kg/m ²)		Obesity (BMI > 30 kg/m ²)	
	Men	Women	Men	Women	Men	Women	Men	Women
AUC (95% CI)	0.950 (0.948–0.952)	0.941 (0.939–0.943)	0.964 (0.962–0.966)	0.951 (0.949–0.953)	0.944 (0.942–0.946)	0.936 (0.934–0.938)	0.957 (0.955–0.960)	0.947 (0.944–0.949)
Optimal cutoffs	87.6	83.4	96.6	91.0	0.521	0.536	0.579	0.587
J-Youden	0.751	0.725	0.802	0.753	0.735	0.712	0.777	0.744
Sensitivity (%)	87.6	84.0	92.9	89.2	88.8	85.4	90.7	89.9
Specificity (%)	87.5	88.5	87.3	86.1	84.7	85.8	87.0	84.5
LR (+)	7.01	7.30	7.31	6.42	5.80	6.01	6.98	5.80
LR (–)	0.14	0.18	0.08	0.13	0.13	0.17	0.11	0.12

Abbreviations: AUC, area under curve; LR (+), positive likelihood ratio; LR (–), negative likelihood ratio.

study. In line with this, in a study of Korean adults, Baik⁵¹ proposes cutoff values of 84–86 cm for men and 78–80 cm for women.

The ROC analysis for the WHtR in the male overweight category provided an optimal cutoff value of 0.521, which was slightly

higher than the value of 0.51 in Liu *et al.*³⁴ In the female overweight category, the cutoff value was 0.536, which was somewhat lower than the value of 0.54 reported by Liu *et al.*³⁴ In the male obesity category, the WHtR cutoff was 0.570, which

was lower than the value of 0.64 established in Lee *et al.*¹³ In the female obesity category, the optimal cutoff value was 0.58, which is considerably lower than the value of 0.70 reported in Lee for obese women. Nonetheless, apart from the differences between the cutoffs in our study and those reported in other research on populations at other geographic locations, the WC and WHtR values obtained for overweight and obesity in both sexes constitute the first cutoff values ever reported for a Colombian adult population. This signifies that our research results will be an important reference for future studies.

Our study had several strengths such as the fact that similar studies have not been previously performed in Colombian adults.^{19,52,53} The strength of the present research is that we studied WC and WHtR between different age groups of a large sample in Colombian adults, which could be used as a reference for our population. In addition, anthropometric data were collected by appropriately trained health professionals who used the same anatomic sites of measurements.

Limitations include the lack of information such as socio-economic, dietary and physical activity patterns, and ethnic factors that modulate growth and levels of adiposity. Another point is the cross-sectional design of the study based on data collection in 2010 with a high prevalence of overweight/obesity. Recently, Parra *et al.*⁵³ using data from the 2000, 2005 and 2010 Colombian Demographic and Health Survey (ENDS) and 2005–2010 National Nutrition Survey (ENSIN), which were conducted concomitantly in the years 2005 and 2010, observed that the prevalence of overweight/obese household increased between 2000 (38.2%) and 2010 (43.1%) ($P < 0.05$), whereas undernourished and dual burden household significantly decreased between 2005 (13.7 and 10.6%, respectively) and 2010 (3.5 and 5.1%, respectively) ($P < 0.05$). Nevertheless, such limitations did not compromise the results obtained here, as they were similar regarding total score by gender and similar to that reported in studies carried out in Colombian.^{19,52,53}

In conclusion, by providing LMS tables for WC and WHtR in adults based on Colombian reference data, we hope to provide quantitative tools for the study of obesity and its complications. Public health interventions and a national strategy to tackle the contributors to excess weight gain and its cardiometabolic consequences at the population level and in different age groups should become a national health priority in Colombia.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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AUTHOR CONTRIBUTIONS

The authors' contributions are as follows: RR-V and JM-T have made a contribution to the conception of this study. EG-J, JFM-E, JS-RV, KG-R, RR-V, JFM-E, FL and JEC-B drafted the protocol and manuscript. All authors read and approved the final manuscript.

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