LMS tables for waist circumference and waist-to-height ratio among Colombian children and adolescents: The FUPRECOL Study

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Abstract

Background: Indices predictive of central obesity include waist circumference (WC) and waist-to-height ratio (WHtR). The aims of this study were 1) to establish a Colombian youth smoothed centile charts and LMS tables for WC and WHtR and 2) to evaluate the utility of these parameters as predictors of overweight and obesity.

Method: A cross-sectional study whose sample population comprised 7954 healthy Colombian schoolchildren [boys n=3460 and girls n=4494, mean (standard deviation) age 12.8 (2.3) years old]. Weight, height, body mass index (BMI), WC and WHtR and its percentiles were calculated. Appropriate cut-offs point of WC and WHtR for overweight and obesity, as defined by the International Obesity Task Force (IOTF) definitions, were selected using receiver operating characteristic (ROC) analysis. The discriminating power of WC and WHtR was expressed as area under the curve (AUC).

Results: Reference values for WC and WHtR are presented. Mean WC increased and WHtR decreased with age for both genders. We found a moderate positive correlation between WC and BMI (r= 0.756, $P < 0.01$) and WHtR and BMI (r= 0.604, $P < 0.01$). The ROC analysis showed a high discrimination power in the identification of overweight and obesity for both measures in our sample population. Overall, WHtR was slightly a better predictor for overweight/obesity (AUC 95% CI 0.868-0.916) than the WC (AUC 95% CI 0.862-0.904).

Conclusion: This paper presents the first sex- and age-specific WC and WHtR percentiles for both measures among Colombian children and adolescents aged 9–17.9 years. By providing LMS tables for Latin-American people based on Colombian reference data, we hope to provide quantitative tools for the study of obesity and its comorbidities.

Keywords: Central obesity; Reference values; Anthropometric indices.

Background

The prevalence of overweight and obesity has become a public health problem worldwide [1]. Substantial evidence indicates that increased body weight and body fat distribution has 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 [5-9]. To estimate the magnitude of this problem, commonly studies use direct indicators 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 remain simple, inexpensive, non-invasive, and validated methods to apply in clinical practice and epidemiological studies [10-14].

Currently, the two most widely used definitions are those of the National Cholesterol Education Program Adult Treatment Panel III (NCEP:ATPIII) and International Diabetes Federation (IDF) focusing specifically on waist circumference, which is a surrogate measure of central obesity [5,14]. In addition to the WC, the WHtR (waist [cm]/height [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 (2012) in a robust meta-analysis that include 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.

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 (LMIC´s) experiencing rapid nutrition transitions such as Latin America or Africa [19,20]. LMIC´s included Colombia are favorable environment to assess body composition because the prevalence of both underweight and overweight individuals is relatively high [19,20]. In addition, it is likely that ethnicity and environmental differences influence body proportions, indicating the usefulness of national references to control for variations between populations. Cut-off values and percentiles for WC and WHtR are available for children and adolescents 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 has not been investigated in a Colombian sample in the Americas. Therefore, the aims of this study were to establish a Colombian smoothed centile charts and LMS tables for WC and WHtR and to evaluate the utility of these parameters as predictors of overweight and obesity among Colombian children and adolescents.

Methods

Design of the study

The present is a cross-sectional study whose sample population consisted of children and adolescents healthy Colombian.

Study population

In Colombia, measures of weight and physical activity have been added to youth health monitoring systems by the government [27] and research institutions. Recently (2015),

physical fitness assessment was added to the FUPRECOL study (*in Spanish* ASOCIACIÓN DE LA **FU**ERZA **PRE**NSIL CON MANIFESTACIONES DE RIESGO CARDIOVASCULAR TEMPRANAS EN NIÑOS Y ADOLESCENTES **COL**OMBIANOS). The FUPRECOL study seeks to establish the general prevalence of cardiovascular risk factors (anthropometric, metabolic and genetic markers) in the study population (children and adolescents aged 9 to 17.9 years living in Bogota, Colombia) [20,28,29] and examine the relationships between physical fitness levels and cardio-metabolic risk factors.

The FUPRECOL study assessments were conducted during the 2014–2015 school year. The sample consisted of children and adolescents 7954 healthy Colombian schoolchildren**,** boys n= 3460 and girls n= 4494, means ± standard deviations (SD) age 12.7 (2.4) y, weight 44.5 (12.3) kg, height 1.49 (0.1) m, BMI 19.7 (3.6) kg/m^2. All schoolchildren were of low-middle socioeconomic status (SES, 1–3 in a scale 1-6 defined by the Colombian government) and enrolled in public elementary and high schools (grades 5 through 11) in the capital district of Bogota, Cundinamarca Department in the Andean region. This region is located at approximately 4°35′56″N 74°04′51″W and at an elevation of approximately 2,625 meters (min: 2,500; max: 3,250) above sea level. Bogota is considered an urban area, with approximately 7,862,277 inhabitants [30]. A convenience sample of volunteers was included and grouped by sex and age with 1-year increments (a total of 9 groups). Power calculations were based on the mean of overweight and obesity from the first 200-400 participants in the ongoing data collection (range, 26-32 kg/m^2), with a group SD of approximately 5.2 kg/m^2. The significance level was set to 0.05, and the required power was set to at least 0.80. The sample size was estimated to be approximately 250 to 500 participants per group. Exclusion factors included a clinical diagnosis of cardiovascular disease, diabetes mellitus 1 and 2, pregnancy, the use of alcohol or drugs, and, in general, the presence of any disease not

directly associated with nutrition. Exclusion from the study was made effective *a posteriori*, without the students being aware of their exclusion to avoid any undesired situations.

Ethics Statement

The Review Committee for Research on Human Subjects at the University of Rosario [Code Nº CEI-ABN026-000262] approved all of the study procedures. A comprehensive verbal description of the nature and purpose of the study and its experimental risks was given to the participants and their parents/guardians. This information was also sent to parents/guardians by regular mail, and written informed consent was obtained from the parents and subjects before they participated in the study. The protocol was in accordance with the latest revision of the Declaration of Helsinki and current Colombian laws governing clinical research on human subjects (Resolution 008430/1993 Ministry of health).

Measures

Anthropometrics variables were measured by a Level 2 anthropometrist certified by the International Society for the Advancement of Kinanthropometry (ISAK), in accordance with the ISAK guidelines [31], in the morning following an overnight fast, at the same time (7:00-10:00 a.m.). Body weight was measured in the subjects' underwear and with no shoes, using electronic scales (Tanita® BC544, Tokyo, Japan) with a low technical error of measurement (TEM = 0.510%). Height (Ht) was measured using a mechanical stadiometer platform (Seca® 274, Hamburg, Germany; TEM = 0.019%). BMI was calculated as the body weight in kilograms divided by the square of height in meters. Waist circumference was measured at the midpoint between the last rib and the iliac crest using a tape measure (Ohaus® 8004-MA, New Jersey, USA; TEM = 0.086%) [20]. WHtR 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 IOTF [32]. According to this definition, the group of subjects with overweight (the equivalent of BMI ≥25 kg/m^2) also contains those who are obese (the equivalent of BMI ≥30 kg/m^2).

Statistical analyses

Anthropometric characteristics from the study sample are presented as mean and standard deviation (SD). 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. Age- and sex-specific table percentiles (3rd, 10th, 25th, 50th, 75th, 90th and 97th) were constructed for WC and WHtR. The associations between WC, WHtR and BMI were tested by means of *Pearson* correlation coefficients. The relation between WC, WHtR and overweight/obesity as defined by IOTF [32] was investigated with Receiver operating characteristic curves (ROC). Cut-off values were derived mathematically from the ROC curves, using the point on the ROC curve with the lowest value for the formula: (1-sensitivity)^2 + (1-specificity)^2. The positive likelihood ratio LR (+) and the negative likelihood ratio LR (-) were also determined. Descriptive statistics was 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 Tables 2 (WC) and 3 (WHtR). Mean BMI was highly comparable in both sexes, and the prevalence of overweight was 25.0% (95% CI:

23.5-26.6%) and 15.8% (95% CI: 14.4-17.3 5%) in girls and boys, respectively. Prevalence of obesity was 9.9% (95% CI: 8.9-11.0%) and 7.5% (95% CI: 6.5-8.5%) in girls and boys, respectively. Mean WC increased and WHtR decrease with age for both genders. In both sexes, we found a moderate positive correlation between WC and BMI (r=0.756, $P < 0.01$) and WHtR and BMI (r= 0.604, $P < 0.01$).

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Receiver operating characteristic analysis showed that both WC and WHtR had a high discriminating power to detect IOTF overweight and obesity (Figure 1 and 2). To overweight category in boy's children, the cut-off point value of 62.7 cm for the WC provided a sensitivity of 89.8%, a LR (+) value of 3.52, specificity of 74.5% and LR (-) value of 0.14. In girl's children, the cut-off point value of 62.8 cm for the WC provided a sensitivity of 82.1%, a LR (+) value of 4.72, specificity of 82.6% and LR (-) value of 0.22. For obesity category in boys, the cut-off point value of 67.9 cm for the WC provided a sensitivity of 87.0%, a LR (+) value of 5.06, specificity of 82.8% and LR (-) value of 0.16. In girls, the cut-off point value of 65.9 cm for the WC provided a sensitivity of 87.0%, a LR (+) value of 5.06, specificity of 82.8% and LR (-) value of 0.16 (Figure 1 and Table 4). ROC curve for WHtR was also obtained and the cut-off point value of 0.459 was used (Figure 2 and Table 4). To overweight category considering this cutoff point, in boys sensitivity was 78,2%, LR (+) value of 5.28, specificity 85.2% and LR (-) 0.26. In girls the cut-off point value was 0.436, sensitivity 84.6%, LR (+) value of 3.83, specificity 77.9% and LR (-) 0.20. To obesity in boys the cut-off point value of 0.485 was used. The sensitivity was 83.5%, LR (+) value of 6.05, specificity 86.2% and LR (-) 0.19. In women, the cut-off point value was 0.472 with sensitivity 79.3%, LR (+) value of 7.02, specificity 88.7% and LR (-) 0.23.

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Discussion

This paper presents the first age- and sex-specific WC and WHtR percentiles for these parameters among Colombian children and adolescents aged 9–17.9 years. These results can be used as a baseline for long-term health surveillance in the city and the country. All of the subjects in our sample experienced a progressive increase in their mean body weight (BW), which coincides with the results of previous studies [33,34]. In our sample, girls aged 9−13.9 years old had higher mean Ht values than boys of the same age. According to Cousiminer (2016), this increase in Ht could be related to physical and sexual development, which generally occurs earlier in female, which is in line with results obtained in other research [36,37].

Both the boys and girls in our sample had similar mean BMI values though the prevalence of overweight and obesity was higher among the girls, which is in consonance with other studies [38-40]. Similarly to Hirschler (2015), who studied a population of indigenous children in Argentina, we observed an increase in mean WC values in relation to age, was more pronounced in boys. Because our data are not longitudinal, we cannot affirm that this increase was progressive as the children became older. Nevertheless, many research studies have found that the distribution pattern of subcutaneous fat varies with age [40-43]. That way, when a person ages there is a tendency for fat to be deposited in the central area of the body instead of in peripheral areas, which helps the risk of cardiovascular disease at an increasingly earlier age [42,43].

Moreover, in line with previous studies [44,45] our results found that for both sex groups, mean WHtR values decreased with age. In the same way as in Wang et al. (2013), who studied a population of children from Beijing (China), our results show a moderate correlation between WC and BMI in both boys and girls. Nonetheless, despite this correlation, we agree with Smith (2007) that it would be useful to know which WC values are considered normal for each BMI level. This would permit the application of corrective measures to those patients with anomalous WC values, thus decreasing their cardiometabolic risk. Our results also showed a positive correlation between WHtR and BMI values in both sex groups. This is in consonance with the results of previous research [48,49], which identified WHtR as an accurate indicator in the prediction of cardiometabolic risk.

Regarding WC percentages for boys up to the age of 13.9, the 50^{th} percentile showed higher values in comparison to the same percentile in girls of the same age. After the age of 14, the girls in the 50^{th} percentile had higher values. These differences between gender groups were less striking in the 97^{th} percentile though an upturn was observed in boys, 11−14.9 years of age, in contrast to the girls. Once again, these results are indicative of sexual dimorphism in body composition [50].

Gender-related differences were also present in the WHtR percentages. More specifically, boys aged 9−13.9 years old had higher WHtR values than girls in the same age group. However, in the 14−17.9 age range, the tendency was reversed, and the girls had higher WHtR values in all percentiles. These results agree with previous research on other sample populations [51,52].

In reference to the ROC analysis, results showed that both the WC and WHtR parameters have a high discrimination power for the detection of overweight and obesity in the sample population of children and adolescents in this study. Accordingly, the optimal cut-

off value for the WC in the male overweight category was found to be 73.8 cm, which exceeded the cut-off value for adolescent girls and also exceeded the values for children of both sexes. These results are similar to those obtained in previous research [44,53]. Concerning obesity, the highest cut-off point was obtained for adolescent girls (76.6 cm), which coincides with previous international studies [54,55].

The ROC analysis for the WHtR in the overweight category produced similar cut-off values for children and adolescents of both sexes. For the obesity category, the values were also similar, especially in obese adolescents of both genders. However, these values were lower than 0.50, which is the value that Bacopoulou et al. (2015) established as a cut-off point for obesity in Greek adolescent boys and girls. In Latin America, for example, populations have disparities in health along with disparities in modifiable risk factors, including low participation in physical activity. LMICs, such as Colombia, are experiencing rapid urbanization and integration with global markets [20]. This has led to changes in diet and physical activity, which in turn have had large effects on body composition and other health-related fitness components [20,56,57]. It is well known that WC and WHtR [8,10] are better predictors of cardiovascular disease risk factors in children than BMI, and prospective and case–control studies have shown that even with a normal BMI, those with lower physical fitness are at increased risk of cardiovascular disease risk and premature death [58,59]. These changes are contributing to a global increase in the prevalence of non-communicable diseases [58]. Therefore, the inclusion of WC and WHtR within health surveillance systems is justifiable and has been recommended [8,10]. Schools may be an ideal setting to monitor youth fitness [60] and could help to formulate specific strategies to promote the future health of youth.

This study had some limitations. First, this study includes participants from only a single region in Colombia; therefore, inferences to all Colombian children and adolescents

should be made cautiously. Second, we have not considered the potential impact of recognized determinants such as socio-economic, dietary and physical activity patterns, and ethnic factors that modulate growth and levels of adiposity. Third, this study includes participants from public schools in one city and thus the data are not fully representative of the full population on the city or the country. However, Bogota is the largest urban center in Colombia comprising about 15% of the country's population. It includes a mix of locally born residents and populations from other regions of the country that relocate there with large racial and cultural diversity. Another limitation is that this study did not include assessments of students attending private schools. This because the study was deployed in collaboration with the Bogota District Education Department, which only has jurisdiction among public schools. However, the public system constitutes the majority of school offering in the city, with 85% of school-age children enrolled in the city public school system. Therefore, inferences to all Bogota or Colombian children and adolescents should be made cautiously. Future population-based studies collecting data for nationally representative samples, such as the one recently conducted in Argentina, are still needed in Colombia and other countries in the region [41-45].This is an area for future research. However, such limitations do not compromise the results obtained when validating our results.

This study also has strengths that should be highlighted. These results are the first percentile values ever obtained for WC and WHtR in Colombian children and adolescents (9−17.9 years if age). Taking advantage of a newly compiled and large population-based sample, this study develops centile references for Colombian schoolchildren using the popular percentile method. This provided an accurate description of the anthropometric characteristics of the population studied and their age-related and gender-related variations. The reference percentiles can be used as a reference with which to compare the body composition of individuals of a corresponding age in the city, country and region. Establishing these

reference percentiles allows for comparison of WC and WHtR in schoolchildren, who vary geographically and demographically, with others in similar settings.

Conclusions

In conclusion, this is the first comprehensive study which determines smoothed age- and sex-specific WC and WHtR percentiles Colombian children and adolescents aged 9-17.9 years old. These growth charts allow to health-care workers in a clinical setting and researchers diagnose and monitor children and adolescents and could be used for early detection of obesity.

Abbreviations

WC: Waist circumference.

WHtR: Waist-to-height ratio.

BMI: Body mass index.

ROC: Receiver operating characteristics curve.

FUPRECOL: Asociación de la fuerza prensil con manifestaciones de riesgo cardiovascular tempranas en niños y adolescentes colombianos.

ISAK: International Society for the Advancement of Kinanthropometry.

TEM: Technical error of measurement.

USA: United States of America.

SD: Standard Deviation.

Ht: Height.

IOTF: International Obesity Task Force.

AUC: Area under the receiver-operating characteristic curves.

BW: Body weight.

Competing interests

The authors declare that they have no competing interests.

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Figure legend

Figure 1. Receiver operating characteristic (ROC) curve of the WC and WHtR to detect overweight (up) or obesity (down) according to the IOFT criteria for Colombian children aged 9–12.9 years. GS: gold standard; AUC: area under the curve (95% confidence interval).

Figure 2. Receiver operating characteristic (ROC) curve of the WC and WHtR to detect overweight (up) or obesity (down) according to the IOFT criteria for Colombian adolescents aged 13–17.9 years. GS: gold standard; AUC: area under the curve (95% confidence interval).

Table 1. Mean values (standard deviation, SD) for body weight (BW), height (Ht), body mass index (BMI), waist circumference (WC) and waist-to-height ratio (WHtR) for Colombian children and adolescents aged 9–17.9 years

Sex	n	Body weight (kg)	Height (cm)	BMI (kg/m^2)	WC (cm)	WHtR
Boys						
9 to 9.9	258	32.1 (7.5)	133.5 (6.5)	17.8 (3.1)	60.8 (6.7)*	0.455 (0.044)**
10 to 10.9	466	34.5 (8.5)	137.3 (7.4)*	18.1 (3.3)	61.7 (8.0)*	0.450 (0.052)**
11 to 11.9	445	37.2 (8.8)*	141.9 (8.2)*	18.3 (3.2)	63.5 (7.6)*	0.448 (0.047)**
12 to 12.9	404	41.3 (9.1)*	147.1 (8.2)*	18.9 (3.2)	64.7 (7.5)*	0.440 (0.047)**
13 to 13.9	401	46.0 (9.8)*	153.5 (9.3)*	19.4 (3.3)**	65.8 (7.7)	0.429 (0.048)
14 to 14.9	443	50.0 (9.7)*	158.9 (9.1)**	19.7 (3.0)**	67.1 (7.1)	0.423 (0.043)**
15 to 15.9	426	54.4 (9.7)*	163.3 (8.9)**	20.3 (3.0)**	69.2 (6.7)	0.424 (0.042)**
16 to 16.9	365	57.7 (8.7)**	166.7 (7.2)**	20.8 (2.9)**	70.6 (7.1)**	0.424 (0.045)**
17 to 17.9	252	60.8 (10.3)**	168.1 (7.4)**	21.5 (3.3)**	72.1 (7.4)**	0.430 (0.044)*
Total	*3460*	*45.5 (13.0)**	*151.9 (14.1)***	*19.4 (3.3)***	*66.0 (8.1)***	*0.436 (0.048)*
Girls						
9 to 9.9	308	32.1 (7.4)	134.6 (7.6)	17.6 (3.0)	59.3 (6.6)	0.441 (0.041)
10 to 10.9	659	35.0 (7.9)	138.4 (7.6)	18.1 (3.0)	60.9 (7.4)	0.439 (0.047)
11 to 11.9	645	38.3 (7.9)	143.7 (7.5)	18.4 (2.9)	62.1 (6.7)	0.432 (0.044)
12 to 12.9	549	42.8 (8.6)	148.5 (7.3)	19.3 (3.0)	63.2 (6.9)	0.426 (0.044)
13 to 13.9	472	47.4 (9.0)	152.4 (6.3)	20.3 (3.2)	65.2 (7.3)	0.427 (0.046)
14 to 14.9	609	51.0 (8.9)	154.6 (6.5)	21.3 (3.3)	67.3 (8.0)	0.436 (0.052)
15 to 15.9	504	52.7 (8.6)	155.7 (6.8)	21.7 (3.1)	68.5 (7.1)	0.440 (0.046)
16 to 16.9	450	53.9 (8.6)	156.4 (5.8)	22.0 (3.1)	68.7 (7.7)	0.440 (0.049)
17 to 17.9	296	55.1 (9.3)	156.8 (6.5)	22.4 (3.6)	69.5 (7.7)	0.444 (0.050)
Total	*4494*	*44.8 (11.5)*	*148.7 (10.1)*	*20.0 (3.5)*	*64.8 (8.0)*	*0.436 (0.047)*

Note: Data values are reported as mean and standard deviation (SD).
Significant difference between boys and girls within the same age group: *$P < 0.01$, **$P < 0.0001$.

Table 2. Smoothed age- and sex-specific percentile of WC (cm) for Colombian children and adolescents aged 9–17.9 years

	n	M	SD	P_3	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	P_{97}
Boys										
9 to 9.9	258	60.8	6.7	51.2	54.0	56.2	59.4	64.3	69.9	75.4
10 to 10.9	466	61.7	8.0	51.6	53.5	56.7	60.3	65.9	72.4	79.0
11 to 11.9	445	63.5	7.6	53.4	56.0	58.1	62.0	67.0	75.5	82.1
12 to 12.9	404	64.7	7.5	54.0	56.5	60.0	63.3	69.0	75.7	83.3
13 to 13.9	401	65.8	7.7	54.6	58.5	61.2	64.6	69.3	75.3	85.5
14 to 14.9	443	67.1	7.1	56.4	60.0	62.5	65.7	70.6	76.7	86.2
15 to 15.9	426	69.2	6.7	59.1	62.0	64.5	68.1	72.1	78.3	86.1
16 to 16.9	365	70.6	7.1	59.5	63.2	66.6	70.0	74.0	78.6	87.7
17 to 17.9	252	72.1	7.4	61.0	64.7	67.6	71.2	75.4	82.3	88.7
Total	*3460*	*66.0*	*8.1*	*53.6*	*56.5*	*60.5*	*65.3*	*70.5*	*76.5*	*84.1*
Girls										
9 to 9.9	308	59.3	6.6	50.1	52.0	54.4	58.0	63.4	68.8	74.5
10 to 10.9	659	60.9	7.4	50.8	53.0	55.8	59.6	64.6	71.0	79.0
11 to 11.9	645	62.1	6.7	52.5	54.8	57.4	60.8	66.0	71.0	76.7
12 to 12.9	549	63.2	6.9	53.0	55.8	58.2	61.9	67.0	72.5	79.1
13 to 13.9	472	65.2	7.3	53.6	57.1	60.3	64.3	69.4	74.3	82.0
14 to 14.9	609	67.3	8.0	55.2	59.0	62.5	66.9	72.0	77.0	82.9
15 to 15.9	504	68.5	7.1	57.0	60.5	64.2	67.5	72.3	77.0	86.0
16 to 16.9	450	68.7	7.7	57.3	60.7	63.8	68.0	72.9	78.3	85.2
17 to 17.9	296	69.5	7.7	58.0	61.0	64.5	68.5	73.3	79.4	88.9
Total	*4494*	*64.8*	*8.0*	*52.2*	*55.5*	*59.0*	*64.0*	*69.5*	*75.1*	*81.9*

M: mean; SD: standard deviation; P: percentile

Table 3. Smoothed age- and sex-specific percentile values of WHtR for Colombian children and adolescents aged 9–17.9 years

	n	M	SD	P_3	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	P_{97}
Boys										
9 to 9.9	258	0.455	0.044	0.395	0.409	0.424	0.447	0.483	0.516	0.553
10 to 10.9	466	0.450	0.052	0.383	0.398	0.418	0.442	0.477	0.519	0.567
11 to 11.9	445	0.448	0.047	0.374	0.399	0.417	0.438	0.472	0.513	0.553
12 to 12.9	404	0.440	0.047	0.373	0.390	0.409	0.429	0.461	0.509	0.557
13 to 13.9	401	0.429	0.048	0.370	0.385	0.401	0.419	0.446	0.489	0.550
14 to 14.9	443	0.423	0.043	0.362	0.381	0.394	0.413	0.443	0.483	0.533
15 to 15.9	426	0.424	0.042	0.367	0.379	0.396	0.416	0.442	0.482	0.528
16 to 16.9	365	0.424	0.045	0.364	0.380	0.399	0.420	0.441	0.484	0.524
17 to 17.9	252	0.430	0.044	0.370	0.386	0.402	0.421	0.453	0.491	0.530
Total	*3460*	*0.436*	*0.048*	*0.370*	*0.388*	*0.404*	*0.427*	*0.457*	*0.501*	*0.546*
Girls										
9 to 9.9	308	0.441	0.041	0.378	0.394	0.413	0.435	0.465	0.495	0.541
10 to 10.9	659	0.439	0.047	0.373	0.390	0.408	0.429	0.463	0.501	0.549
11 to 11.9	645	0.432	0.044	0.370	0.386	0.402	0.427	0.456	0.491	0.531
12 to 12.9	549	0.426	0.044	0.360	0.376	0.395	0.421	0.450	0.484	0.532
13 to 13.9	472	0.427	0.046	0.352	0.376	0.398	0.424	0.452	0.482	0.537
14 to 14.9	609	0.436	0.052	0.364	0.385	0.403	0.430	0.464	0.501	0.549
15 to 15.9	504	0.440	0.046	0.366	0.387	0.411	0.435	0.468	0.498	0.538
16 to 16.9	450	0.440	0.049	0.363	0.388	0.410	0.434	0.467	0.497	0.552
17 to 17.9	296	0.444	0.050	0.371	0.389	0.410	0.434	0.473	0.512	0.562
Total	*4494*	*0.436*	*0.047*	*0.365*	*0.385*	*0.405*	*0.429*	*0.461*	*0.496*	*0.539*

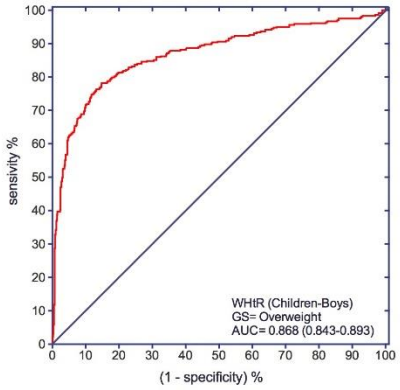
M: mean; SD: standard deviation; P: percentile

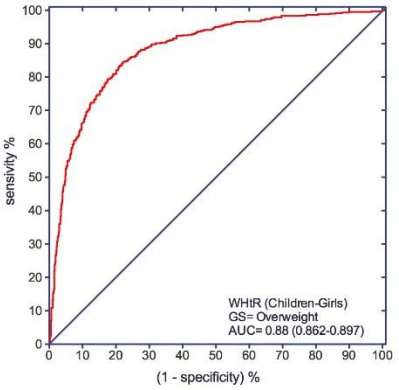
Table 4. Area under the receiver-operating characteristic curves (AUC) for WC and WHtR indices among Colombian children and adolescents aged 9–17.9 years

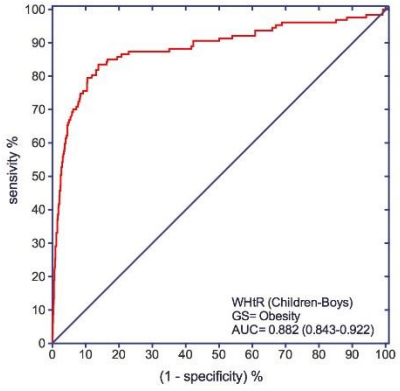
	WC				WHtR			
	Overweight		Obesity		Overweight		Obesity	
Children	Boys (9-12.9 y)	Girls (9-12.9 y)	Boys (9-12.9 y)	Girls (9-12.9 y)	Boys (9-12.9 y)	Girls (9-12.9 y)	Boys (9-12.9 y)	Girls (9-12.9 y)
AUC (95% CI)	0.895 (0.874-0.917)	0.889 (0.872-0.906)	0.882 (0.845-0.919)	0.904 (0.878-0.929)	0.868 (0.843-0.893)	0.881 (0.862-0.897)	0.882 (0.843-0.922)	0.899 (0.873-0.925)
Optimal cut-offs	62.7	62.8	67.9	65.9	0.459	0.436	0.485	0.472
J-Youden	0.643	0.647	0.647	0.698	0.634	0.625	0.697	0.68
Sensitivity (%)	89.8%	82.1%	80.3%	87.0%	78.2%	84.6%	83.5%	79.3%
Specificity (%)	74.5%	82.6%	84.4%	82.8%	85.2%	77.9%	86.2%	88.7%
LR (+)	3.52	4.72	5.15	5.06	5.28	3.83	6.05	7.02
LR (-)	0.14	0.22	0.23	0.16	0.26	0.20	0.19	0.23
	Overweight		Obesity		Overweight		Obesity	
Adolescents	Boys (13-17.9 y)	Girls (13-17.9 y)	Boys (13-17.9 y)	Girls (13-17.9 y)	Boys (13-17.9 y)	Girls (13-17.9 y)	Boys (13-17.9 y)	Girls (13-17.9 y)
AUC (95% CI)	0.862 (0.829-0.894)	0.878 (0.861-0.895)	0.850 (0.789-0.911)	0.892 (0.864-0.919)	0.902 (0.876-0.929)	0.887 (0.871-0.904)	0.916 (0.871-0.962)	0.914 (0.888-0.94)
Optimal cut-offs	73.8	68.9	74.1	76.6	0.458	0.445	0.463	0.468
J-Youden	0.630	0.605	0.631	0.550	0.699	0.619	0.762	0.704
Sensitivity (%)	75.5%	81.9%	81.7%	63.4%	78.6%	82.2%	91.7%	90.3%
Specificity (%)	87.5%	78.6%	81.4%	91.6%	91.3%	79.7%	84.5%	80.1%
LR (+)	6.04	3.83	4.39	7.55	9.03	4.05	5.92	4.54
LR (-)	0.28	0.23	0.22	0.40	0.23	0.22	0.10	0.12

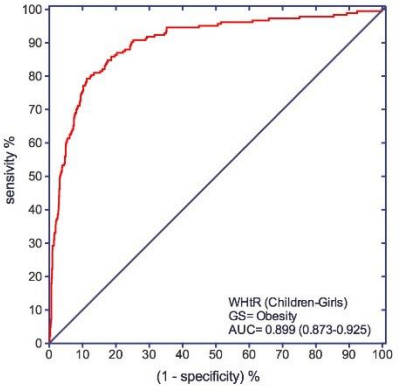
AUC: area under curve; LR (+): positive likelihood ratio; LR (-): negative likelihood ratio

Waist circumference

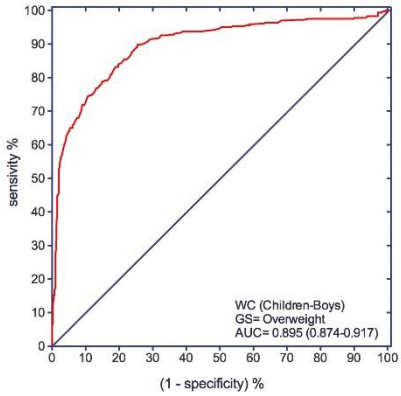


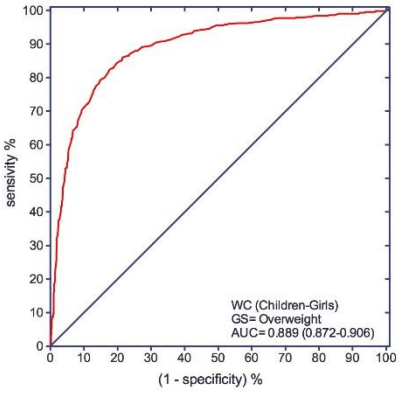


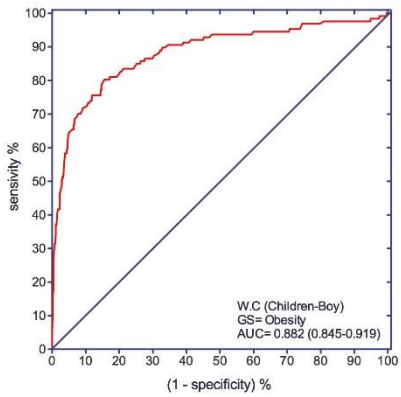


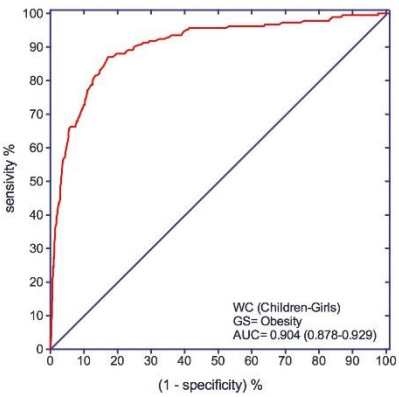


Waist-to-height ratio

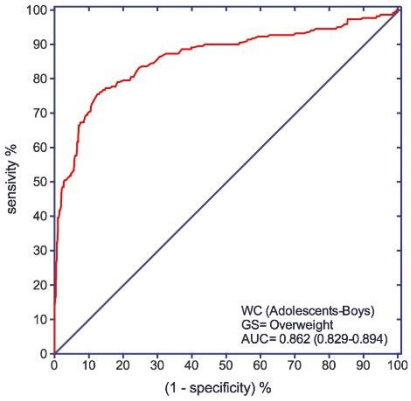


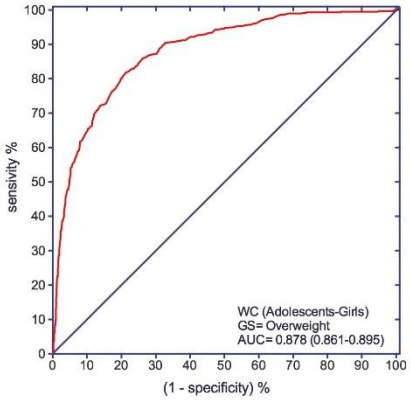


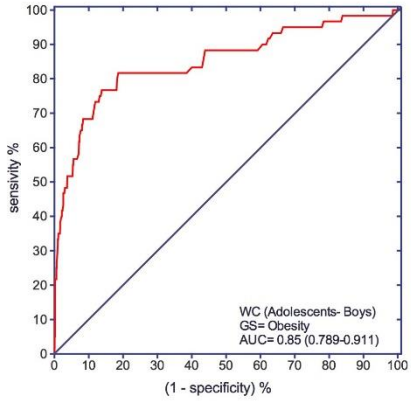


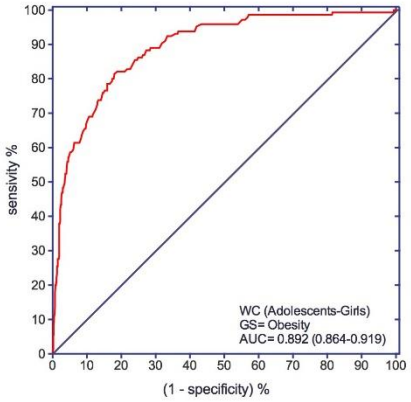


Waist circumference









Waist-to-height ratio