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Waist-to-Height: Cutoff Matters in Predicting Metabolic Syndrome in Mexican Children

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Abstract

Background: Body-mass index (BMI), waist circumference (WC), and, recently, waist-to-height ratio (WHtR) have been proposed as clinical indexes to identify children at cardiometabolic risk. The aim was to identify the usefulness of WHtR cutoffs, WC, and BMI as predictors of metabolic syndrome in Mexican children, according to BMI *z*-scores, and the severity of obesity to cardiometabolic risk factors and metabolic syndrome.
Methods: This was a cross-sectional study of 214 overweight/obese and 47 normal-weight Mexican children 6–12 years old. Children were divided in groups according to BMI *z*-scores. Anthropometric and biochemical measurements were determined. Receiver-operating characteristic (ROC) curves and areas under the curves were calculated to compare the abilities of the anthropometric measurements to predict metabolic syndrome.
Results: The overall prevalence of metabolic syndrome was 23.3%, ranging from 11.0% in the overweight group to 73.9% in the severely obese one. Children with metabolic syndrome had significantly higher WHtR, WC, BMI, percentage of body fat, triglycerides, total cholesterol, low-density lipoprotein cholesterol (LDL-C), systolic and diastolic blood pressure, and lower high-density lipoprotein cholesterol (HDL-C). A WHtR cutoff point of 0.59 from the ROC curve was identified as strong predictor of metabolic syndrome in our population, whereas a cutoff of 0.5 showed very poor specificity (22.7%). WC predicted metabolic syndrome as well.
Conclusion: Cutoff values for WHtR make a difference in predicting metabolic syndrome. A cutoff of 0.59 for WHtR strongly predicted metabolic syndrome; it might be a simpler to use screening tools and counters for short people. Further studies are required to determine the cutoff points for an accurate prediction, because there are few in children and none in Mexico.

Introduction

Obesity in children is a rapidly expanding disease across the world.[1] In Mexico, the prevalence is 26% in school-aged children, increasing from 1999 to 2006 by 39.7%.[2] Childhood obesity is associated with insulin resistance and increases the risk of developing diabetes, cardiovascular disease (CVD), hypertension, dyslipidemia, and long-term vascular complications.[3] It can also lead to the metabolic syndrome,[1,3,4] which is also rapidly expanding among children.[5] Both cross-sectional and prospective studies in children have linked metabolic syndrome, or clusters of factors considered to be part of it, to diabetes[3] and CVD,[3,6] among other complications. Specifically, abdominal obesity has been related to metabolic syndrome in children and adolescents.[7–10] Body mass index (BMI), waist circumference (WC), and, more recently, waist-to-height ratio (WHtR) have been proposed as clinical indexes to identify children and adolescents at risk, but there is still controversy regarding which one performs as the best predictor.

BMI, for instance, is not a measure of fatness, nor of fat distribution. In children and adolescents, it has other limitations due to variation in growth rates and maturity levels, as well as the need to use percentile tables.[11] WC, on the other hand, has been recommended as a good predictor of abdominal fat.[12] Studies in children and adolescents suggest that WC can identify metabolic and cardiovascular risk factors,[13–16] as well as metaoblic syndrome. However, the use of WC also requires age and sex-specific cutoff points. Besides, even in the same population, shorter people are known to be at high risk of metabolic complications.[17] Higher rates of cardiovascular events have also been demonstrated in short men[18] and women.[19] For countering these interindividual metabolic differences, WC alone may not be sufficient, and

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height needs to be considered.[20] Recently, several studies in children[21–24] have suggested that WHtR is more strongly associated with CVD risk factors than is BMI. In addition, WHtR may be simpler to use and does not need to be expressed relative to sex and age.[25]

Because clusters of risk factors for metabolic and CVD tend to track fairly well from childhood into adulthood[6,26] and the duration of exposure has been associated with morbidity/mortality,[4,27] the identification of children and adolescents with elevated risk factor profiles is of great importance to establish appropriate prevention and treatment programs. In addition, very few studies have been performed in Mexican children.[28] Clinicians need to rely on a simple, standardized anthropometric parameter to identify which patients are at greater risk of cardiometabolic complications and thus, need a closer follow-up.

Therefore, the aim of this study was to identify a cutoff for WHtR for the population studied and to assess the use of WHtR, WC, BMI, and percentage of body fat (%BF) as predictors for metabolic syndrome in Mexican children with diverse degrees of obesity and the impact of the severity of obesity on the prevalence of metabolic syndrome.

Subjects and Methods

Study population

We studied a cross-sectional sample of 214 overweight/obese 6- to 12-year-old children and 47 children with normal BMI from eight schools representative of Monterrey, Mexico, during June, 2010. Of the 261 children, 83% lived in urban and 17% in suburban areas. All subjects were Mexican-Hispanic. Within each school, subjects were selected by a systematic random method; the response rate for participation was 67%. Inclusion criteria were attendance at school and a 12-h overnight fast. Exclusion criteria were known diabetes mellitus as well as blood pressure, glucose, or lipid-altering medications. Approvals by the Ethics and Research Committees of the School of Medicine TEC de Monterrey and by the State Education Secretariat were obtained, as was written informed consent from parents.

Clinical and anthropometric assessment

Anthropometric measurements were performed in all subjects ($n = 261$) within each school. Height was measured to the nearest 0.5 cm (portable Seca®-stadiometer, Ontario, Canada) and weight was determined to the nearest 0.1 kg while children wore light clothing and no socks or shoes (TANITA TBF 300A® scale, Arlington Heights, IL). %BF was measured by bioimpedance (same scale). WC was measured to the nearest 0.1 cm at the level of the umbilicus[16,29] with a flexible fiberglass tape while the subjects were standing, after gently exhaling, and with no clothing on the area. BMI was calculated as weight (kilograms) divided by the square of height (meters). WHtR was calculated as waist divided by height. All anthropometric measures were performed by the

Table 1. Demographic Characteristics of the Study Sample

	MetS (+) n = *55*	*MetS (−)* n = *181*	P *value*
Gender−no (%, CI)			
Male	28 (50.9%, 38.1–63.6)	74 (40.9%, 34.0–48.2)	0.189[a]
Female	27 (49.1%, 36.4–61.9)	107 (59.1%, 51.8–66.0)	
Tanner−no (%, CI)			
Prepubertal*	26 (47.3%, 34.7–60.2)	95 (52.5%, 45.2–59.6)	0.498[a]
Pubertal*	29 (52.7%, 39.8–65.3)	86 (47.5%, 40.4–54.8)	
Age (yr)	9.04 (8.56, 9.52)	9.45 (9.23, 9.68)	0.112
Weight (kg)	55.7 (51.1, 60.2)	42.3 (40.9, 43.7)	<0.001
Height (cm)	141.2 (138.0, 144.4)	139.3 (137.9, 140.7)	0.279[b]
%BF	39.9 (37.5, 42.3)	28.4 (27.3, 29.6)	<0.001
WC (cm)	90.6 (87.5, 93.6)	75.8 (74.3, 77.2)	<0.001
WC (percentile)	94.7 (93.0, 96.5)	72.9 (69.7, 76.0)	<0.001
BMI (kg/m^2)	27.3 (26.1, 28.5)	21.6 (21.1, 22.1)	<0.001
BMI (percentile)	98.5 (98.0, 98.9)	86.4 (83.6, 89.3)	<0.001
BMI (z-score)	2.30 (2.21, 2.40)	1.39 (1.26, 1.51)	<0.001
WHtR	0.642 (0.626, 0.657)	0.544 (0.535, 0.554)	<0.001
SBP (mmHg)	110.7 (108.0, 113.5)	105.4 (104.4, 106.5)	0.001[b]
SBP (percentile)	70.8 (64.3, 77.3)	59.9 (56.8, 63.0)	<0.001
DBP (mmHg)	62.2 (60.0, 64.4)	58.3 (57.3, 59.2)	0.001
DBP (percentile)	52.2 (46.0, 58.4)	42.0 (39.1, 45.0)	0.004
Fasting glucose (mg/dL)	84.9 (82.4, 87.4)	83.6 (82.1, 85.2)	0.625
TC (mg/dL)	169.6 (160.3, 179.0)	152.9 (148.0, 157.8)	0.008
LDL-C (mg/dL)	114.4 (106.2, 122.6)	101.6 (97.9, 105.3)	0.003
HDL-C (mg/dL)	33.4 (31.8, 35.0)	43.2 (40.8, 45.6)	<0.001
TG (mg/dL)	193.9 (173.2, 214.5)	102.4 (96.5, 108.2)	<0.001

Data represent mean (95% CI) unless otherwise specified. *P* values come from Mann-Whitney-U test unless otherwise noted.
*Prepubertal was considered as Tanner stage I and pubertal as Tanner II-IV.[31]
[a]*P* value for proportions from chi-squared test.
[b]*P* value for heteroscedastic variables from Welch's t-test.
MetS, metabolic syndrome; CI, confidence interval; %BF, percentage of body fat; WC, waist circumference; BMI, body-mass index; WHtR, waist-to-height ratio; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; TG, triglycerides.

Table 2. Clinical and Laboratory Parameters by BMI z-Score Categories

	Normal weight (n = *43*)	*Overweight* (n = *109*)	*Moderately obese* (n = *61*)	*Severely obese* (n = *23*)	P *value*
Gender – no (%, CI)					
Male	10 (23.3%, 13.2–37.7)	47 (43.1%, 34.2–52.5)	29 (47.5%, 35.5–59.8)	16 (69.6%, 49.1–84.4)	0.003[a]
Female	33 (76.7%, 62.3–86.8)	62 (56.9%, 47.5–65.8)	32 (52.5%, 40.2–64.5)	7 (30.4%, 15.6–50.9)	
Tanner – no (%, CI)					
Prepubertal*	21 (48.8%, 34.6–63.2)	55 (50.5%, 41.2–59.7)	38 (62.3%, 49.7–73.4)	7 (30.4%, 15.6–50.9)	0.069[a]
Pubertal*	22 (51.2%, 36.8–65.4)	54 (49.5%, 40.3–58.8)	23 (37.7%, 26.6–50.3)	16 (69.6%, 49.1, 84.4)	
Age (yr)	9.74 (9.25, 10.24)	9.73 (9.45, 10.02)	8.95 (8.59, 9.31)	7.91 (7.26, 8.56)	<0.001
%BF	19.3 (17.5, 21.2)	29.3 (28.3, 30.3)	37.6 (36.2, 38.9)	44.7 (40.3, 49.0)	<0.001[b]
WC (cm)	65.6 (63.6, 67.6)	77.2 (75.7, 78.7)	86.7 (84.7, 88.7)	94.4 (88.7, 100.0)	<0.001[b]
WC (percentile)	45.2 (39.4, 51.1)	77.6 (75.2, 80.0)	93.7 (92.6, 94.9)	99.2 (98.8, 99.7)	<0.001[b]
WHtR	0.471 (0.461, 0.482)	0.55 (0.541, 0.556)	0.624 (0.616, 0.632)	0.681 (0.655, 0.707)	<0.001[b]
SBP (mmHg)	103.2 (101.1, 105.3)	107.1 (105.6, 108.6)	107.7 (105.5, 109.9)	108.6 (104.5, 112.7)	0.015
SBP (percentile)	53.3 (46.8, 59.9)	63.2 (59.0, 67.4)	66.8 (60.9, 72.6)	64.3 (54.8, 73.7)	0.021
DBP (mmHg)	58.0 (56.0, 60.1)	59.6 (58.1, 61.0)	59.0 (57.4, 60.6)	60.0 (56.5, 63.6)	0.612
DBP (percentile)	41.4 (35.2, 47.7)	45.5 (41.3, 49.6)	44.1 (39.1, 49.1)	45.8 (36.0, 55.6)	0.741
Fasting glucose (mg/dL)	82.6 (80.0, 85.2)	85.3 (83.2, 87.3)	82.0 (79.5, 84.5)	84.9 (80.2, 89.5)	0.172
TC (mg/dL)	150.8 (144.3, 157.3)	151.5 (144.7, 158.2)	163.5 (154.4, 172.6)	175.7 (159.5, 191.9)	0.004
LDL-C (mg/dL)	94.8 (89.1, 100.6)	101.1 (96.1, 106.0)	113.4 (105.9, 120.8)	116.3 (103.1, 129.6)	<0.001[b]
HDL-C (mg/dL)	42.4 (39.8, 45.1)	41.7 (38.4, 44.9)	40.0 (35.5, 44.5)	36.9 (34.1, 39.7)	0.484
TG (mg/dL)	94.3 (82.5, 106.0)	113.6 (104.3, 122.8)	134.9 (119.6, 150.2)	196.8 (151.4, 242.2)	<0.001[b]
MetS – no (%, CI)					
Positive	0 (0.0%, 0.0–8.2)	12 (11.0%, 6.4–18.3)	26 (42.6%, 31.0–55.1)	17 (73.9%, 53.5–87.5)	<0.001[a]
Negative	43 (100.0%, 91.8–100.0)	97 (89.0%, 81.7–93.6)	35 (57.4%, 44.9–69.0)	6 (26.1%, 12.5–46.5)	

Data represent mean (95% CI) unless otherwise stated. *P* values were obtained with ANOVA unless otherwise noted. Obese subjects were further classified as moderately obese (z-score of 2.0 to 2.5) or severely obese (z-score above 2.5).

*Prepubertal was considered as Tanner stage I and pubertal as Tanner II-IV.[31]

[a]*P* values for proportions from chi-squared test.

[b]*P* values for heteroscedastic variables from Welch's F-test.

CI, confidence interval; %BF, percentage of body fat; WC, waist circumference; BMI, body-mass index; WHtR, waist-to-height ratio; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; TG, triglycerides.

same trained examiner in all children to control for interobserver variability.

Blood pressure was measured in every subject by the same physician, using an aneroid sphygmomanometer (Welch-Allyn®, Skaneateles Falls, NY) with a proper cuff according to the subjects' size and following the appropriate technique.[30] Two measurements were obtained while the subjects were calm and seated, and the average was calculated. Tanner stage was self-evaluated by means of schematic drawings from which, prompted by the physician, children selected the most appropriate self-image.[31]

Laboratory assessment

Venous blood samples were obtained from 236 subjects (193 overweight/obese and 43 normal-weight children) after a 12-h overnight fast. Samples were kept at 2–8°C, centrifuged within the first 3 h, and then refrigerated again at 2–8°C. Serum total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), triglycerides (TG), and glucose were measured by reflective photometry (Beer–Lambert law) using an automated analyzer (Architect C8000, Abbott®, Abbott Park, IL), with an intra-and interassay coefficient of variation below 4.7%.

Statistical analysis

Analysis was performed with the SPSS statistical package v17 (SPSS, Chicago, IL) and Microsoft Excel 2007. A P value of 0.05 or less was considered statistically significant. Confidence intervals for proportions were obtained using the Wilson score method.

In Table 1, data are presented either as absolute number (percentage) or mean [95% confidence interval (CI)]. Normality of subgroups of each continuous variable was revised graphically and by both the Kolmogorov–Smirnov test (with Lilliefors significance correction) and Shapiro–Wilk test. Height and systolic blood pressure (SBP) variables passed all tests and were tested for equality of variances by Levene; both showed heteroscedasticity, and therefore the P value was obtained from a Welch t-test. For the rest of the continuous variables, the P value was obtained from a Mann–Whitney U-test. A chi-squared test was used for proportions.

In Table 2, data represent the mean (95% CI), unless otherwise stated. Children were classified based on their BMI z-score as normal weight ($z < 1.0$), overweight ($1.0 \leq z < 2.0$), moderately obese ($2.0 \leq z < 2.5$), and severely obese ($2.5 \leq z$). P values for continuous variables were obtained with analysis of variance (ANOVA) if the groups passed a Levene test of equal variance. Otherwise a Welch F-test was employed. A chi-squared test was used for proportions.

A receiver operating characteristic (ROC) curve analysis was performed. The areas under each ROC curve (AUC), its standard error, and 95% CI were calculated using a nonparametric approach. The AUC has been described as the probability that a test will correctly identify a pair of patients with and without a disease who were randomly selected from the population.[10] The P value for differences in AUC from different variables was calculated using the Hanley and McNeil method.[32] To identify an optimal cutoff point for each variable, we identified the point in the ROC curve with the shortest distance to the (0,1) corner as described in Moreno et al.[10]

Definitions

We defined metabolic syndrome according to the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) criteria modified by Cook for its use in adolescents[33]; that is, any three out of five altered parameters including elevated WC (≥90th percentile), hypertriglyceridemia (≥110 mg/dL), low HDL-C ≤ 40 mg/dL), fasting hyperglycemia (≥110 mg/dL), and elevated blood pressure [systolic blood pressure/diastolic blood pressure (DBP) ≥ 90th percentile].

Based on the Centers for Disease Control and Prevention charts (2000) and the recommendations of the American Academy of Pediatrics,[34] overweight was defined for the initial screening of the population as BMI > 85th and <95th percentiles and obesity as >95th percentile. We standardized the BMI value for age and sex by conversion to a z-score. Obesity was defined on the basis of a threshold BMI z-score >2.0 or more. Obese subjects were further classified as moderately obese (z-score 2.0–2.5) or severely obese (z-score >2.5). Subjects who had a z-score of 1.0–1.9 were classified as overweight.

Results

Anthropometric and metabolic parameters

Anthropometric and metabolic parameters for subjects with and without metabolic syndrome are shown in Table 1. Subjects with metabolic syndrome had significantly higher weight, %BF, WC, BMI, WHtR, SBP, DBP, TC, TG, and LDL-C, as well as significantly lower HDL-C.

Metabolic syndrome and obesity severity

According to the BMI z-score, WHtR, WC, and %BF increased significantly with increasing obesity, as did cardiovascular risk factors such as SBP, TG, TC, and LDL-C (Table 2). Interestingly, age showed a significantly decreasing trend as obesity severity increased, which indicates that the youngest subjects were the most severely obese (P value <0.001 for linear trend test). This can also be seen graphically (Fig. 1)

The overall prevalence of metabolic syndrome was 23.3% (95% CI 18.4–29.1). Combining the overweight and obese groups, 28.5% (95% CI 22.6–35.1) had metabolic syndrome. Table 2 also shows that as the severity of obesity increased the proportion of subjects from each weight category that presented metabolic syndrome increased from 0.0% to 73.9% (P value <0.001 for linear trend test). Regarding gender, boys were significantly more severely obese compared with girls (P value <0.001 for linear trend test).

ROC curve analysis

A ROC curve was constructed for WHtR, BMI (percentile and z-score), %BF, and WC (percentile) to predict the presence of metabolic syndrome. All variables showed to predict significantly better than chance (Table 3) (P values <0.001). WHtR had the greatest AUC, which indicates that it was the best overall predictor. It also had the least standard error, showing a better statistical inference capability. However, when the AUC for WHtR was compared with other variables, it was only significantly better than %BF ($P = 0.042$).

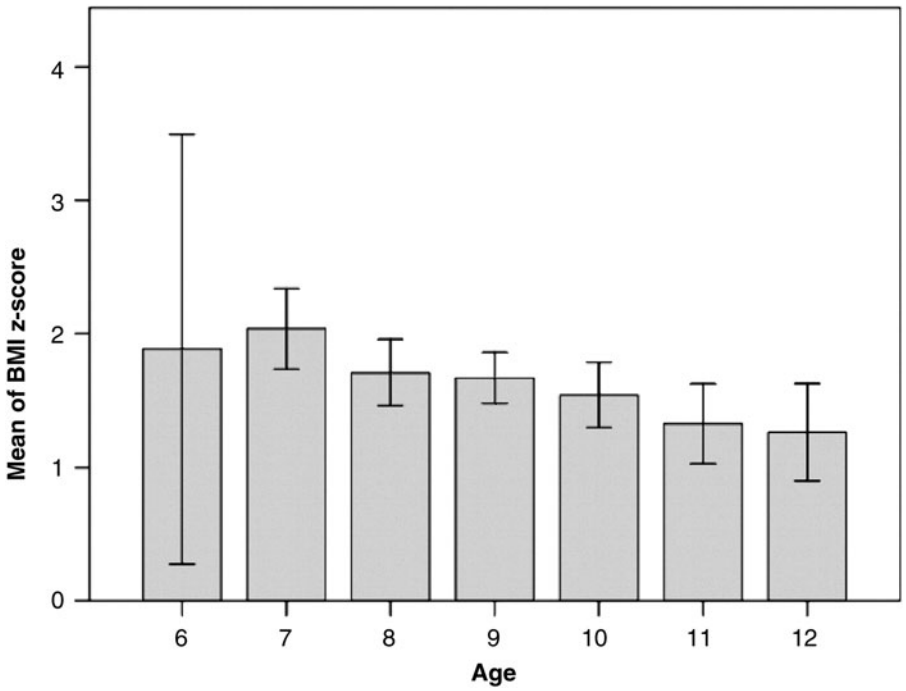

FIG. 1. Body mass index (BMI) *z*-score shows a tendency to decrease as age increases. Error bars represent 95% confidence intervals.

Our calculated optimal cutoff values resulted in 0.592 for WHtR, 90.0 for WC (percentile), 97.3 for BMI (percentile), 1.92 for BMI (*z*-score), and 33.9 for %BF. Table 4 shows sensitivity (Se), specificity (Sp), positive and negative likelihood ratios (LR), and accuracy for these cutoffs and also compares them with common used cutoffs. WHtR has a good predictability performance with 0.592 as a cutoff (81.8% Se, 78.5% Sp), whereas the use of the usual 0.5 cutoff provides better sensitivity (100.0%) but at the cost of extremely poor specificity (22.7%). WC (percentile) performed better in both (89.1% Se, 80.7% Sp) than WHtR. BMI (percentile) was slightly better than its *z*-score. Using the usual 95 percentile as cutoff for BMI increases the sensitivity to 98.2% but lowers dramatically the specificity to 55.8%. Except for WC, the rest of the measurements showed less specificity than WHtR. No variable presented a likelihood ratio (+) equal or greater than 5.

Discussion

We examined the relation of varying degrees of obesity with WHtR, WC, %BF, and BMI as predictors of metabolic syndrome in Mexican children aged 6–12 years, and studied the effect of the severity of obesity on the prevalence of metabolic syndrome. Our results showed that, measured by BMI *z*-score, as obesity severity increased, WHtR, WC, %BF, SBP, TG, TC, and LDL-C showed a significant increasing trend, whereas HDL-C showed a decreasing one. This highlights the negative effects of increasing BMI in children. We found a high prevalence of metabolic syndrome: 23.3% in the total sample and 28.5% in the overweight/obese subjects. As obesity severity increased, the percentage of subjects with metabolic syndrome in each group augmented also. Prevalence of metabolic syndrome among those that were overweight was 11.0%, which increased to 42.6% in the moderately obese and to 73.9% in the severely obese groups. None of the normal-weight children had metabolic syndrome.

In addition, our results showed that, according to the BMI *z*-score, younger children were the most severely obese. This is especially alarming because cluster-tracking studies have demonstrated that obesity and multiple metabolic and cardiovascular risk factors persist from childhood into adulthood in 25% to 60% of cases,[4,6,26] and that the longer their

Table 3. Receiver Operating Characteristic Curve Analysis

	AUC (95% CI)	*SE*	P *value*[a]	P *value*[b]
WHtR	0.885 (0.843–0.928)	0.022	<0.001	
WC (percentile)	0.882 (0.835–0.929)	0.024	<0.001	0.872
BMI (percentile)	0.874 (0.827–0.920)	0.024	<0.001	0.527
BMI (z score)	0.874 (0.828–0.920)	0.024	<0.001	0.464
%BF	0.849 (0.796–0.901)	0.027	<0.001	0.042

[a]Null hypothesis is AUC = 0.5.
[b]Null hypothesis is AUC for variable = AUC for WHtR. P value from Hanley and McNeil's method (30).
AUC, area under the curve; CI, confidence interval; SE, standard error under the nonparametric assumption; WHtR, waist-to-height ratio; WC, waist circumference; BMI, body-mass index; %BF, percentage of body fat.

Table 4. Predictability Characteristics for Specific Cut-Offs Points

	Cut-off	*Se (95% CI)*	*Sp (95% CI)*	*LR (+)*	*LR (−)*	*Accuracy*
WHtR	0.592[a]	81.8% (69.7–89.8)	78.5% (71.9–83.8)	3.80	0.232	79.2%
	0.500	100% (93.4–100.0)	22.7% (17.2–29.3)	1.29	0.000	40.7%
WC (percentile)	90.0[a]	89.1% (78.2–94.9)	80.7% (74.3–85.8)	4.61	0.135	82.6%
BMI (percentile)	97.3[a]	85.5% (73.8–92.4)	74.0% (67.2–79.9)	3.29	0.197	76.7%
	95.0	98.2% (90.4–99.7)	55.8% (48.5–62.8)	2.22	0.033	65.7%
BMI (z score)	1.92[a]	85.5% (73.8–92.4)	72.9% (66.0–78.9)	3.16	0.199	75.9%
%BF	33.8[a]	78.2% (65.6–87.1)	76.8% (70.1–82.4)	3.37	0.284	77.1%

[a]Cut-off corresponds to the one with the shortest distance to the point (0,1) in the ROC curve space.
Se, sensitivity; Sp, specificity; LR, likelihood ratio; WHtR, waist-to-height ratio; WC, waist circumference; BMI, body-mass index; %BF, percentage of body fat.

persistence, there is an increase in morbidity/mortality.[4,27] These facts support the importance of looking for early weight-related complications in overweight and obese children as young as 6 years old by identifying easy-to-use and non-expensive screening measures that the clinician can apply to recognize or predict the appearance of metabolic syndrome to monitor or examine children at particular risk further.

Our findings agree with the results of other studies in children who have found an association of WC[13–16] with cardiovascular and metabolic risk factors, as well as with metabolic syndrome.[7–10,28] Some studies indicate that WC in conjunction with BMI is a better predictor of metabolic risk than either measure alone,[35] whereas other studies suggest that WC predicts metabolic syndrome beyond that predicted by BMI alone.[7–10,15] In children, WC is limited by the need to use age-specific cutoffs. Moreover, in most countries, like Mexico, there are no population-based reference values for WC. Furthermore, WC has been measured at numerous sites,[7–10,15,16,21,28,29] and small changes in the location of the waist measurement can alter associations with risk factor measures[36] and possibly with disease risk.[37] Besides, all short people who are at higher metabolic risk[38] would be missed if they do not meet the WC cutoffs that have been derived from the general population.

To overcome these limitations in children, WHtR has been proposed for a more practical use in clinical application because it offers several potential advantages for clinical use: it varies only slightly by age and sex among children and thus does not require percentile tables or *z*-scores.[16,21,25]

A single cutoff point of 0.5 for WHtR has been used by several authors and found to be more strongly associated with increased cardiovascular risk in children.[16,21–24,37] Recently, a study reported a potential overestimation of abdominal obesity in very young children (2–5 years old) when the WHtR cutoff of 0.5 was used.[39] Even though our sample of subjects is older (6–12 years), in an attempt to overcome any overestimation, we analyzed the ROC curves of our sample of children and obtained a cutoff value of 0.59 for WHtR to predict metabolic syndrome in our population (positive LR of 3.68 or negative LR of 0.24, for having or not metabolic syndrome, respectively) with a good sensitivity and specificity. This might mean that the previously proposed cutoff of 0.5 is not appropriate for our ethnic group of Mexican–Hispanic children. In addition, our results showed an extremely poor specificity of 22.7% using the traditional cutoff point of 0.5, and it is noteworthy that in our population even children without metabolic syndrome presented a mean WHtR of 0.544, which is above 0.5. We also have to consider that the cutoffs to define obesity and cardiometabolic risk in adults in Mexico are lower than those established internationally.[40] In Mexico, adults with BMI > 27.5 kg/m^2 are considered obese,[41] and the cutoff point related to cardiometabolic risks for waist circumference is >80 cm in women and >90 cm in men.[42] However, there are currently no population-based BMI, WHtR, or WC guidelines for Mexican children, and scarce data are available.[28,43]

Although a study has shown no difference in BMI and WHtR to identify children with adverse risk factors,[37] recently a few authors have found WHtR a better correlate than BMI for obesity[44] and some of the cardiometabolic risk factors in children.[21–24] In our findings, WHtR was the anthropometric measurement with the greatest AUC for predicting the presence of the metabolic syndrome, in comparison to percentile BMI and WC. Thus, WHtR may be a potentially useful substitute measure for abdominal obesity across different age, gender, or ethnic populations. Unlike BMI and WC, WHtR does not need to be standardized for age because it is age- and sex- independent.[21,37]

This study had certain limitations in that it was cross-sectional and thus causality cannot be inferred. This sample consisted of Mexican children, which may limit its generalizability to other ethnic groups. We used nonpopulation-specific reference values for WHtR, BMI *z*-scores, and WC, but there are no national references for the Mexican children population.

In conclusion, the prevalence of metabolic syndrome increases directly with the degree of obesity from 11.0% in the overweight group to 73.9% in the severely obese one. Although both WC and WHtR identified risk of metabolic syndrome in children, our results add to the body of knowledge because few studies have been done in Mexican children; our study also set a WHtR cutoff of 0.59, as well as establishing that WHtR was the strongest predictor of metabolic syndrome. Further studies are required to validate cutoff values and the effectiveness of these anthropometric indices to predict children at risk of metabolic syndrome.

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Author Disclosure Statement

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