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POPULATION STUDY ARTICLE

A waist-to-height ratio of 0.54 is a good predictor of metabolic syndrome in 16-year-old male and female adolescents

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BACKGROUND: We aimed to determine the sensitivity and specificity of selected anthropometric indicators as predictors of cardiovascular risk in adolescents.
METHODS: Cross-sectional study in 678 adolescents (16.8 y ± 0.3) from an infancy cohort. Weight, height, waist circumference (WC), and hip circumference were measured. Body mass index (BMI), waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) were estimated. MetS was diagnosed with IDF/AHA/NHLBI. Optimal cutoffs of BMI, WC, WHR, and WHtR for diagnosing MetS were determined using ROC analysis.
RESULTS: In males, WHtR (0.96) had the greatest area under the ROC curve, followed by WC (0.95) and BMI (0.93). In females, BMI (0.84) had the greatest area under the ROC curve (0.84), followed by WHtR (0.83) and WC (0.83). In both sexes, the optimal WHtR cutoff for MetS diagnosis was 0.54. A BMI of 26.9 in males and 26.3 in females were the optimal cutoffs for diagnosing MetS. Finally, WC values of 92 and 81.6 cm in males and females, respectively, were the optimal cutoffs for MetS diagnosis.
CONCLUSIONS: In both sexes, a WHtR value of 0.54 was a good predictor of MetS. In males and females, the optimal cutoff of BMI for Mets diagnosis was below the values for diagnosing obesity.

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INTRODUCTION

Obesity in childhood and adolescence is associated with metabolic and endocrine disorders, which predispose children to early development of cardiovascular disease and type-2 diabetes mellitus (T2DM).[1,2] A clustering of metabolic abnormalities, including obesity, hyperglycemia, dyslipidemia, and hypertension, has been referred to as Metabolic Syndrome (MetS). MetS is an independent predictor of cardiovascular morbidity and mortality, and identifies greater additional biological risk beyond the sum of the individual risk factor related to obesity and insulin resistance (IR).[3,4]

Excessive weight gain has dramatically increased in Chilean children and adolescents over the past two decades. In 2015, 52% of 1st graders and 44% of 9th graders were either overweight or obese, according to a population survey.[5] A study conducted in Chilean children and adolescents, ages 10 to 15, found a high prevalence of obesity (16.1%), MetS (7.3%) and insulin resistance (IR) (26%). Among obese participants, prevalence rates of MetS and IR were especially high (62 and 29%, respectively).[6] Similarly, in a sample of 16-year-old Chilean adolescents of mid- to low socioeconomic status, 16% had obesity, 79% had at least one cardiovascular risk, and 9.5% had MetS. One in three adolescents had abdominal obesity, 70% had low high-density lipoproteins (HDL-chol) and fasting hyperglycemia prevalence was 8.7%.[7]

Anthropometric indicators of obesity such as waist circumference (WC), waist-to-hip ratio (WHR) and waist-to-height radio (WHtR) are associated with adverse cardiometabolic consequences in children and adolescents.[8–11] Abdominal fat is metabolically active and has been linked to insulin hypersecretion and MetS. In obesity and IR, fat tissue increases the plasma concentration of free fatty acids, adipokines and proinflammatory cytokines.[12–14] Although WC correlates with the amount of intra-abdominal visceral fat, it is also associated with abdominal subcutaneous fat and total body fat[15–18]. However, WHtR best expresses central adiposity and, therefore, is better able to determine the cardiovascular risk associated with MetS in all age groups.[11–15] In adults, it was found that WHtR is strongly and positively correlated with BMI ($r = 0.85$–0.91) and body fat percentage ($r = 0.69$–0.76), assessed with plethysmography.[19] Additionally, in adults, WHtR was as reliable as Body mass index (BMI) in predicting endothelial dysfunction compared to WHR and WC.[20] Studies suggest that WHtR has a stronger association with cardiovascular risk factors in children, adolescents, and adults compared to BMI.[8–11,15] However, differences between WHtR and BMI are relatively small.[9,19,21] Inexpensive, easy-to-measure anthropometric indicators which have good sensitivity to identify obesityrelated cardiometabolic disorders might be useful in the early detection of individuals with increased biological risk. In this study, we aimed to compare the sensitivity and specificity of BMI, WC, WHR, and WHtR as predictors of cardiovascular risk in male and female adolescents and to determine the optimal cutoff values for MetS diagnosis.

METHODS

Participants

We studied 16–17-year-old adolescents living in Santiago, Chile, from low-to-middle socioeconomic status (SES), who were part of follow-up study beginning in infancy. Participants were recruited at 4 months from public healthcare facilities in the southeast area

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of Santiago ($n = 1791$) to participate in a randomized controlled trial of iron supplementation to prevent iron deficiency anemia (IDA). They were born at term of uncomplicated vaginal births, weighted > 3.0 kg, and were free of acute or chronic health problems.[22] They were assessed for developmental outcomes in infancy, 5, 10, and 15 years. At 16 y, those with complete data ($n = 678$) were also assessed for obesity/cardiovascular risk.[7] The study has been approved by the institutional review boards of the University of Michigan, Institute of Nutrition and Food Technology, University of Chile, and University of California, San Diego. Participants and their primary caregiver provided informed and written consent, which was obtained according to the norms for Human Experimentation, Code of Ethics of the World Medical Association (Declaration of Helsinki, 1995).

Anthropometric assessment

Weight (kg), height (cm), waist and hip circumference (cm) were measured by physician-investigators. Standardized procedures were used to measure weight to the closest 0.1 kg, using a SECA scale (SECA 703, Seca GmbH & co. Hamburg, Germany), and height to the closest 0.1 cm, using a Holtain stadiometer. BMI (kg/m^2). BMI *Z* score for age (BAZ) was estimated and weight status was evaluated according to WHO references[23]. WC and hip circumference (HC) were measured with non-elastic flexible tape (Seca 201, Seca GmbH & co. Hamburg, Germany) at the highest point of the iliac crest around the abdomen and at the level of the greater trochanter, respectively, and recorded to the nearest 0.1 cm.[24] Measurements were taken twice, with a third measurement if the difference between the first two exceeded 0.3 kg for weight, 0.5 cm for height, and 1.0 cm for waist and hip. WC, HC, and height were used to calculate WHtR and WHR.

Cardiometabolic assessment

Systolic and diastolic blood pressures (SBP and DBP) were measured in the non-dominant arm with a standard mercury sphygmomanometer in the morning after 15 min at rest, according to the National High Blood Pressure Education Working Group recommendations; the mean of three measurements was used for analysis.[25] Fasting serum total glucose (Gli), total cholesterol (TChol), triglycerides (TG), HDL, and insulin levels were measured after a 12-h overnight fast. Radioimmunoassay (RIA, DCP Diagnostic Products Corporation, LA) with intra-assay CV of 5.1% and inter-assay CV of 7.1% for 14.4 uUI/ml, and a sensitivity of 1.2 uUI/ml was used for insulin determination. Glucose was measured with enzymatic-colorimetric test (QCA S.A. Amposta, Spain). Baseline insulin sensitivity was calculated using the homeostasis model assessment (HOMA) method [HOMA = fasting insulin (uUI/dl)×fasting glycaemia (mg/dl)/405]. Cholesterol profile (HDL and TG mg/dl) was determined using the drychemical method (Vitros, Johnson & Johnson, Clinical Diagnostics Inc.).

Definition of metabolic syndrome

MetS was diagnosed with the joint IDF/AHA/NHLBI phenotype, which includes having three of five risk factors using the following definitions: abdominal obesity (WC ≥ 80 and ≥ 90 cm in females and males, respectively); high blood pressure (SBP ≥ 130 mmHg and/or DBP ≥ 85 mmHg); hypertriglyceridaemia (TG ≥ 150 mg/dl); low HDL (HDL ≤ 50 and ≤40 mg/dl in females and males, respectively); and fasting hyperglycemia (Gli ≥ 100 mg/dl).[26] Adolescents in the sample were not taking any antihypertensive, lipid-lowering, or hypoglycemic medications.

Statistical analysis

All variables were checked for normality of distribution (Shapiro–Wilk test) before the analysis.

Statistical analysis included Student's *t* test and Wilcoxon's rank-sum test for comparison of mean or median values of anthropometric and cardiometabolic variables. The χ^2 test was used for comparison of categorical variables. Receiver operating characteristic (ROC) analysis was used to find the optimal cutoff of BMI, WC, WHR, and WHtR for MetS diagnosis in males and females. A test with perfect discrimination has a ROC plot that passes through the upper left corner, indication of 100% sensitivity and 100% specificity. A ROC plot closer to the upper left corner denotes greater accuracy of the test. To determine the optimal cutoffs for MetS diagnosis, the point on the ROC curve with maximum Youden Index [sensitivity−(1−specificity)] was calculated. Next, the values were verified with the likelihood ratio for a positive result (LR+) and the post-test probability (the proportion of participants above cutoffs who truly have the MetS). Data were analyzed using Stata for Windows V.15.0 (Lakeway Drive College Station, Texas).

RESULTS

Anthropometric characteristics and individual components of MetS are presented for males and females in Table 1. A total of $n = 678$ adolescents (52% males) were evaluated. Participants' mean age was 16.8 y (0.3 SD). Males had significantly higher values of height, weight, and WHR, and lower values of BMI, HC, and WHtR compared to females. As for the cardiometabolic profile, males had significantly higher levels of SBP, DBP and fasting glucose and lower values of insulin, total cholesterol and HDL cholesterol than females. No difference was found in the prevalence of MetS between males (8.5%) and females (8.8%).

In males (Fig. 1), WHtR had the greatest area under the ROC curve (0.96), followed by WC (0.95) and BMI (0.93), suggesting a greater accuracy in predicting MetS. In females (Fig. 2), BMI was the anthropometric indicator with the greatest area under the ROC curve (0.84), followed by WHtR (0.83) and WC (0.83).

Table 1. Anthropometric characteristics and MetS-related biomarkers in male and female adolescents in the sample ($n = 678$)

Variables	Males ($n = 354$)	Females ($n = 324$)	*P* value
Age (years)	16.8 (0.3)	16.8 (0.4)	NS[a]
Weight (kg)	69.0 ± 13.9	61.8 ± 13.1	<0.001
Height (cm)	171.3 ± 6.1	159.6 ± 6.0	<0.001
Body mass index (kg/m^2)	22.3 (5.2)	23.4 (5.7)	0.030[a]
Body mass index *z* score	0.5 (1.6)	0.7 (1.5)	NS[a]
Waist circumference (cm)	81.2 ± 11.1	81.3 ± 11.8	NS
Hip circumference (cm)	93.9 ± 8.1	96.3 ± 8.8	<0.001
Waist-to-height ratio	0.46 (0.08)	0.50 (0.09)	<0.001[a]
Waist-to-hip ratio	0.85 (0.07)	0.84 (0.09)	<0.001[a]
Systolic blood pressure (mmHg)	115.4 ± 10.4	108.9 ± 9.8	<0.001
Diastolic blood pressure (mmHg)	70.8 ± 7.0	67.7 ± 6.7	<0.001
Fasting glucose (mg/dl)	90.6 ± 9.6	86.5 ± 9.0	<0.001
Fasting insulin (uUI/ml)	6.0 (5.1)	7.1 (5.0)	<0.001[a]
HOMA-IR	1.3 (1.1)	1.5 (1.0)	NS[a]
Total cholesterol (mg/dl)	143 (29.3)	153.9 (32.8)	<0.001[a]
HDL cholesterol (mg/dl)	36.9 (11.5)	41.7 (14.9)	<0.001[a]
Triglycerides (mg/dl)	71.5 (45.5)	76.3 (43.3)	NS[a]
Metabolic syndrome (%)	8.5	8.8	NS[b]

Values are mean ± SD, median(IQR), and relative frequencies. Two-tailed Student's *t* test for independent samples, except as indicated
[a]Wilcoxon rank-sum test
[b]χ^2 (Pearson)

In Table 2, the optimal cutoff points of anthropometric indicators to predict MetS in male and female adolescents are presented. In males, cutoffs of 26.9 for BMI, 92.0 cm for WC, 0.91 for WHR, and 0.54 for WHtR had the best sensitivity and specificity for MetS diagnosing. In females, the optimal cutoffs for MetS diagnosis were 26.3 for BMI, 81.6 cm for WC, 0.87 for WHR and 0.54 for WHtR. In males, the percentage of correctly classified participants was higher than females. Also, the probability of having MetS if the adolescent was above the optimal cut-off point of BMI, WC, WHR, and WHtR was markedly higher in males compared with females.

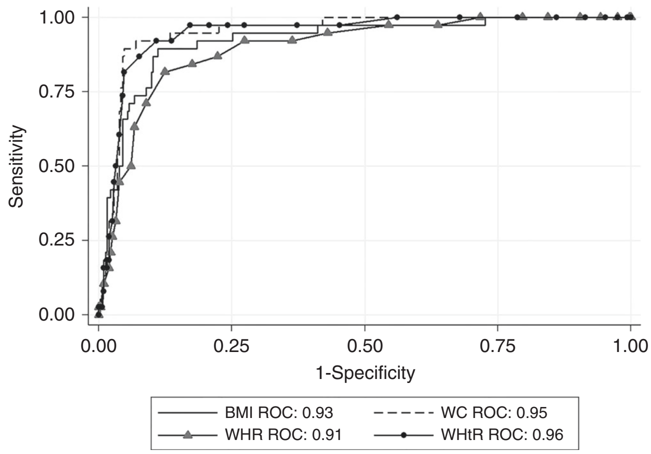

Fig. 1 ROC curves of anthropometric indicators as predictors of metabolic syndrome in 16-year-old male adolescents. BMI Body mass index, WC waist circumference, WHR waist-to-hip ratio, WHtR waist-to-height ratio

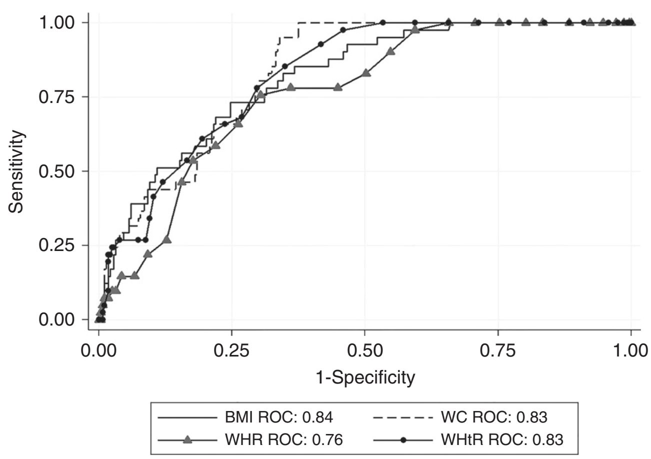

Fig. 2 ROC curves of anthropometric indicators as predictors of metabolic syndrome in 16-year-old female adolescents. BMI Body mass index, WC waist circumference, WHR waist-to-hip ratio, WHtR waist-to-height ratio

The cardiometabolic profile of participants by optimal cutoff values of BMI, WC, WHR, and WHtR are shown in Table 3. In males and females with BMI ≥ 26.9 and ≥26.3, respectively, we found significantly higher values of all MetS-related biomarkers. In the sample, 18.9% of men and 26.5% of women had BMI values equal to or greater than the optimal cutoff point. In males, participants with WC ≥ 92.0 cm had significantly higher values of SBP, DBP, fasting insulin, TChol, and TG. Similarly, in females with WC values ≥ 81.6 cm significantly higher values of SBP, DBP, fasting insulin, and TG were observed. Males with WHR ≥ 0.91 and females with values ≥0.87 had significantly higher values in all MetS biomarkers, with the exception of fasting glucose and TChol in females. In both sexes, WHtR ≥ 0.54 was associated with significantly higher values of all MetS-related biomarkers, except for fasting glucose and TChol in females.

DISCUSSION

Main findings

This study aimed to compare the sensitivity and specificity of BMI, WC, WHR, and WHtR as predictors of cardiometabolic risk in Chilean adolescents between 16–17 years of age, as measured by MetS. We found that WHtR and BMI, along with WC, which is a component of the MetS, had high sensitivity and specificity for the diagnosis of MetS. A study examining the association of total and central adiposity with cardiovascular risk in eutrophic and obese adolescents (13.2 y) showed that BMI and WHtR were associated with higher levels of triglycerides and total cholesterol and low HDL cholesterol and apolipoprotein B levels in the obese participants.[27] In our sample, WHtR in males and BMI in females had the highest sensitivity and specificity to define an optimum cutoff value for predicting MetS. These results are consistent with those obtained by the Bogalusa Heart Study, in children aged 5–17 y ($n = 2498$).[28] WHtR was a good predictor of altered LDL and HDL concentrations whereas BMI performed well in predicting high levels of fasting insulin, SBP, and DBP. Similarly, in the Childhood and Adolescence Surveillance and Prevention of Adult Non-communicable Disease-IV Study conducted in a representative sample of children and adolescents ages 6–18 y from Iran ($n = 4811$), BMI, WC, and WHtR were the most accurate indicators

Table 2. Optimal cutoff values of BMI, WC, WHR, and WHtR to predict metabolic syndrome in male and female adolescents

	Cutoff	Sensitivity (%)	Specificity (%)	Correctly classified	LR+	AUC	Post test probability	
							(+test)	(−test)
Males ($n = 354$)								
Body mass index (BMI)	26.9	96.7	87.4	88.2	7.7	0.935	[35%,48%]	[0%,2%]
Waist circumference (WC; cm)	92.0	92.1	92.9	92.9	18.7	0.950	[44%,64%]	[0%,3%]
Waist-to-hip ratio (WHR)	0.91	86.7	87.8	87.6	7.0	0.911	[32%,48%]	[1%,3%]
Waist-to-height ratio (WHtR)	0.54	93.3	92.6	92.7	12.5	0.960	[44%,64%]	[0%,2%]
Females ($n = 324$)								
Body mass index (BMI)	26.3	78.6	78.4	78.6	3.6	0.840	[21%,32%]	[1%,5%]
Waist circumference (WC; cm)	81.6	96.4	63.9	69.8	2.8	0.830	[18%,23%]	[0%,4%]
Waist-to-hip ratio (WHR)	0.87	95.1	66.1	63.9	2.7	0.760	[18%,24%]	[0%,3%]
Waist-to-height ratio (WHtR)	0.54	72.3	72.8	72.6	2.8	0.830	[16%,26%]	[2%,6%]

Table 3. Cardiovascular and metabolic profile in males and females according to optimal cutoff values of BMI, WC, WHR and WHtR

Males ($n = 354$)	BMI < 26.9 ($n = 287$)	BMI ≥ 26.9 ($n = 67$)	WC < 92.0 ($n = 297$)	WC ≥ 92.0 ($n = 57$)	WHR < 0.91 ($n = 281$)	WHR ≥ 0.91 ($n = 73$)	WHtR < 0.54 ($n = 295$)	WHtR ≥ 0.54 ($n = 59$)
Systolic blood pressure (mm Hg)	110.7 ± 9.9	118.4 ±± 10.9[a]	113.9 ± 9.7	123.2 ± 10.7[a]	111.0 ± 9.9	117.5 ± 11.7[a]	113.7 ± 9.6	123.6 ± 10.3[a]
Diastolic blood pressure (mm Hg)	68.4 ± 6.8	72.6 ± 7.2[a]	70.0 ± 6.8	74.6 ± 6.8[a]	68.4 ± 6.7	72.8 ± 7.3[a]	70.0 ± 6.6	74.7 ± 7.8[a]
Fasting glucose (mg/dl)	88.1 ± 8.8	90.4 ± 11.6[a]	90.3 ± 8.6	91.7 ± 13.5	88.5 ± 8.8	89.0 ± 11.9	90.3 ± 8.7	91.9 ± 13.2
Fasting insulin (uUI/ml)	6.1 (4.3)	9.9 (8.4)[b]	5.6 (4.2)	11.6 (8.1)[b]	6.3 (4.4)	9.5 (9.1)[b]	5.6 (4.3)	10.2 (8.0)[b]
Total cholesterol (mg/dl)	145.5 (30.0)	156.2 (40.9)[b]	142.6 (27.9)	149.8 (43.0)[b]	146.2 (30.9)	152.4 (41.9)[b]	142.6 (26.7)	151.8 (46.3)[b]
HDL-cholesterol (mg/dl)	40.3 (14.4)	35.9 (11.3)[b]	37.8 (11.8)	31.4 (10.4)[b]	40.2 (14.3)	35.4 (12.5)[b]	37.7 (12.2)	32.2 (11.2)[b]
Triglycerides (mg/dl)	70.8 (38.1)	98.9 (75.2)[b]	67.7 (39.1)	103.8 (71.2)[b]	71.4 (40.7)	91.1 (68.3)[b]	67.6 (40.0)	103.3 (80.8)[b]
Metabolic syndrome (%)	2.0	33.8[c]	1.4	59.6[c]	3.5	29.9[c]	0.7	48.3[c]
Females ($n = 324$)	BMI < 26.3 ($n = 238$)	BMI ≥ 26.3 ($n = 86$)	WC < 81.6 ($n = 220$)	WC ≥ 81.6 ($n = 104$)	WHR < 0.87 ($n = 207$)	WHR ≥ 0.87 ($n = 117$)	WHtR < 0.54 ($n = 220$)	WHtR ≥ 0.54 ($n = 104$)
Systolic blood pressure (mm Hg)	110.7 ± 9.9	117.6 ± 11.2[a]	105.6 ± 8.1	113.6 ± 10.1[a]	110.1 ± 9.8	115.7 ± 10.9[a]	106.8 ± 8.6	113.3 ± 10.6[a]
Diastolic blood pressure (mm Hg)	68.4 ± 6.8	72.2 ± 7.1[a]	65.7 ± 5.9	70.5 ± 7.0[a]	67.8 ± 6.5	71.6 ± 7.3[a]	66.5 ± 6.3	70.2 ± 7.0[a]
Fasting glucose (mg/dl)	88.2 ± 8.9	90.1 ± 11.2[a]	85.9 ± 8.5	87.4 ± 9.6	88.5 ± 8.8	88.7 ± 10.5	86.4 ± 8.4	86.7 ± 10.1
Fasting insulin (uUI/ml)	6.0 (4.2)	9.7 (8.3)[b]	6.8 (4.0)	8.6 (5.9)[b]	6.1 (4.2)	8.0 (6.2)[b]	6.9 (4.0)	8.7 (6.5)[b]
Total cholesterol (mg/dl)	145.6 (30.4)	153.0 (39.4)[b]	152.7 (31.2)	155.2 (36.7)	146.3 (30.1)	148.8 (34.9)	152.9 (32.3)	156.0 (36.6)
HDL-cholesterol (mg/dl)	40.3 (14.5)	36.0 (11.3)[b]	41.7 (17.1)	41.6 (10.7)	40.3 (14.0)	37.4 (13.9)[b]	42.3 (17.3)	40.7 (11.2)[b]
Triglycerides (mg/dl)	70.8 (38.1)	97.0 (74.3)[b]	72.6 (39.3)	83.3 (46.2)[b]	68.4 (37.9)	86.5 (53.1)[b]	73.3 (41.9)	83.3 (47.8)[b]
Metabolic syndrome (%)	1.5	32.1[c]	1.6	28.4[c]	2.2	18.7[c]	3.6	20.2[c]

BMI body mass index, *WC* waist circumference (cm), *WHR* waist-to-hip ratio, *WHtR* waist-to-height ratio
[a]Student's *t* test
[b]Wilcoxson rank-sum test
[c] χ^2 test

for predicting cardiovascular risk factors.[29] Although, BMI for age and WHtR did not differ in their ability to identify children with adverse risk factors, it is worth noting that the optimal cutoffs value of BMI for MetS diagnosis in our sample were below the cutoff for obesity diagnosis according to WHO 2007 and CDC 2000 standards.[23,30] This suggests that biological risk associated with increased body fat is being underestimated in adolescents. In non-Hispanic white US adolescents, Peterson et al., found that the tri-ponderal mass index was a more reliable estimator of body fat than BMI.[31] Furthermore, in a sample of $n = 3091$ US children (ages 7–17) from the Bogalusa Heart Study, Mokha et al. validated WHtR as predictors of cardiovascular risk and reported that WHtR performed better than BMI in predicting the cardiovascular risk in children with and without obesity.[8] These results are consistent with those obtained by Khoury et al. in a representative sample of the US population of children and adolescents.[10]

WHtR has been suggested as a useful measure of cardiovascular risk and a cutoff value of 0.50 and 0.54 has been proposed to identify children and adults with increased cardiometabolic risk, which is similar to the cutoff obtained in our study.[8,9,32,33] Other studies in children and adolescents report results similar to ours. Using data from the National Health and Nutrition Examination Survey III, Kahn et al. found that WHtR performed better than sex- and age-specific BMI percentiles to identify US children and adolescents with adverse cardiovascular risk factors.[34] Similarly, in $n = 209$ Chilean children (ages 6–17), WHtR was the best predictor of components aggregation of MetS and the optimal cutoff was 0.55.[35] In the Bogalusa Study, overweight children with WHtR in the top tertile were 2–3 times more likely to have cardiovascular risk factors than those with low WHtR.[36] Finally, two studies conducted in US and Japanese children are also in line with our findings.[8,37] US children and adolescents with a WHtR ≥ 0.5 were more likely to have significant adverse levels of LDL cholesterol, HDL cholesterol, triglycerides, and insulin.[8] In Japanese children aged 9–13 years, WHtR performed better in predicting total cholesterol, triglycerides, LDL cholesterol and atherogenic index compared to BMI, WHR, and WC.[37] In this sample, WHtR was the most sensitive indicator for males and the second most sensitive indicator in female for diagnosing MetS and the optimal cutoff value was the same for both sexes (0.54). This facilitates use and proves its utility at the clinical and population level.

We observed sex differences in the four anthropometric indicators used to identify adolescents with higher biological risk WE found that if the adolescent was above the optimal cut-off point for all anthropometric indicators, the likelihood of having MetS was higher in males than females. Thus, some females may have lower cardiovascular risk as measured by the MetS despite having increased values of BMI, WC, WHR, and WHtR. Several studies show a sexual dimorphism in the cardiometabolic risk associated with the increased body fat mass.[38,39] Several studies show that body fat distribution has a greater impact on cardiometabolic risk compared to total adiposity. Males with excess weight usually have visceral fat deposits, whereas in women with excess weight, subcutaneous fat deposits predominate.[40,41] Although our research did not identify potential protective factors of cardiometabolic risk in females with higher body fat, our findings confirm the importance of estimating the optimal cutoff point of each anthropometric indicator separately by sex, in order to identify adolescents at greater biological risk.

Limitations and strengths

This study has limitations that should be considered when interpreting its results. First, our sample is not representative of the Chilean adolescent population, as this comprised adolescents from low to middle SES between a narrow range of 16–17 years. Our findings, however, may be equally relevant for several of reasons. The prevalence of obesity and cardiometabolic risk is significantly higher in individuals of low to middle SES according to population-based surveys.[42,43] Second, low- to middle-SES adolescents are highly exposed to risk factors that have a direct effect on the development of MetS.[6,7,42–45] Third, studies in children and adolescents of all SES levels have found similar values for the WHtR.[8,35,37] A further limitation is the cross-sectional nature of the study, which limits the ability to draw conclusions related to the temporality of these associations. Future studies should aim to longitudinally explore the performance of these indicators in predicting the risk of cardiometabolic disorders in adulthood. Yet, our study contributes with scientific evidence to select the best anthropometric indicators to identify early cardiovascular risk. Also, it provides knowledge that allows nutritional diagnosis using inexpensive, easy-to-measure anthropometric indicators which are based on biological risk and are potentially useful in both clinical and population settings. Last, our study observed sex differences in the effectiveness of these anthropometric indicators to identify adolescents at greater cardiometabolic risk. To the best of our knowledge, this has not been described in adolescents.

Finally, although a controversy exists on how to diagnose the MetS in children and adolescence, in this study we use the joint IDF/AHA/NHLB criteria. This represents the consensus of several major organizations in an attempt to unify criteria to diagnose MS in a population older than 15 years.[26]

CONCLUSION

WHtR, WC, and BMI-z are good predictors of MetS in adolescents. Although BMI was one of the three best indicators associated with cardiovascular risk, especially in females, the cutoff point of greater sensitivity and specificity for predicting biological risk was below the cutoff point for obesity diagnosis. The use of WHtR might have advantages over BMI *z*-score and WC percentile related to the ease of calculation and application at the individual- or population-level, and because the same cutoff value can be used in both sexes.

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AUTHOR CONTRIBUTIONS

Conceptualization, R.B. and F.V.; Methodology, R.B., P.C.B., F.V.; Formal Analysis, F.V., P. C.B.; Investigation, F.V., R.B.; Data Curation, R.B.; Writing-Original Draft Preparation, F. V., R.B.; Writing-Review & Editing, E.B., S.G., P.C.B.; Supervision, R.B., S.G.; Project Administration, R.B., E.B.; Funding Acquisition, S.G., R.B., P.C.B.

ADDITIONAL INFORMATION

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