Waist circumference shows the highest predictive value for metabolic syndrome, and waist-to-hip ratio for its components, in adolescents

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21 **Abbreviations**

22 MetS, Metabolic syndrome

23 ROC, Receiver-operator curves

24 IL-6, Interleukin 6

25 TNF- α , Tumour Necrosis Factor alpha

26 hs-CRP, High-sensitivity C-reactive protein

27 WHR, Waist-to-hip ratio

28 WHtR, Waist-to-height ratio

29 BMI, Body mass index

30 WC, Waist circumference

31 AUC, Area under the curve

32 ISAK, International society for the advancement of kinanthropometry

33 BP, Blood pressure

34 LDL-C, Low-density lipoprotein-cholesterol

35 HDL-C, High-density lipoprotein-cholesterol

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ABSTRACT

Metabolic syndrome (MetS) is increasing in adolescents, which urges the need to find early predictors of its presence. This study aims to assess which anthropometric measure for obesity provides the greatest predictive value for the development of MetS in Spanish adolescents. A cross-sectional study was performed on 1001 adolescents (13.2 ± 1.2 y) randomly recruited from schools in south-east Spain. Anthropometric measures were correlated with the components of metabolic syndrome (triglycerides, glucose, blood pressure and HDL-cholesterol), as well as inflammation markers (IL-6 and TNF- α , hs-CRP and ceruloplasmin). Receiver-operator curves (ROC) were created to determine the predictive value of these variables for MetS. Boys had higher values of all anthropometric parameters compared to girls, but the prevalence of MetS was significantly higher in girls. Waist-to-hip ratio (WHR) was the only parameter that correlated significantly with all biochemical and inflammatory variables in boys. In girls, WHR, BMI, waist-to-height ratio (WHtR), waist circumference (WC) and body fat percentage correlated only with plasma insulin levels, systolic and diastolic pressures and ceruloplasmin. In both groups, all anthropometric measures were able to predict MetS, ($AUC > 0.94$). In particular, WC was able to predict MetS with $AUC = 1.00$. However, WHR was able to predict a higher number of components of MetS. WHR was the anthropometric index that showed the highest predictive value for MetS components, whereas WC was the one that best predicted the MetS among the population of adolescents studied. These findings justify the need to incorporate WHR and WC determinations into daily clinical practice to predict the MetS.

Keywords: Anthropometric indexes; Metabolic syndrome; Obesity; Inflammation; Adolescents.

1. Introduction

It is well-known that body adiposity is associated with an increased risk of cardiovascular disease [1,2] and, in particular, the development of Metabolic Syndrome (MetS) [3]. In this regard and considering the increasing prevalence of overweight and obesity among the adolescent population, it is essential to be able to identify precociously those individuals with MetS or at risk of suffering it [4].

Currently, different anthropometric indicators are used to predict the risk of MetS in the clinical field, which are based on anthropometric measures such as weight, height, or waist and hip circumferences. However, there is no consensus on the best anthropometric index to predict MetS in adolescents, since results show substantial differences [5-8].

Recent studies show that waist circumference (WC) determination, in addition to BMI, improves the predictive capacity of MetS risk in overweight adolescents [9-11]. Other studies, however, do not support that WC measurement or BMI calculation as accurate procedures to identify individuals at risk for MetS [12]. On the other hand, it has been proposed that WC and waist-to-height ratio (WhtR) are more powerful predictors than the BMI for MetS in adolescents [13]. Regarding the waist-to-hip ratio (WHR) and its predictive ability of MetS, the existing results with adolescent population are eminently contradictory. Jung et al [14] concluded that WHR has a lower predictive capacity of MetS in adolescents, compared to other anthropometric indexes such as BMI. However, other authors, like Zaki et al [15], reported that WHR represents the anthropometric index with the greatest predictive value for MetS among adolescents of both sexes. In this scenario, new studies are needed to analyze in depth the predictive value of these parameters and anthropometric indexes in order to allow a precise prediction of the risk of MetS in adolescent population. Therefore, the

objective of this study was to assess which anthropometric parameter provides the greatest predictive value for the development of MetS in a population of Spanish adolescents.

2. Methods and materials

2.1 Study design and sample

The present is a cross-sectional study whose sample population consisted of 1001 adolescents, 13.2 ± 1.2 years of age, all of Spanish origin and similar socioeconomic status. The subjects attended 18 schools in the provinces of Granada and Almeria (south-east of Spain), where we randomly selected two classes per grade from which to invite participants. The study was previously approved by the Board of Education of the Andalusian Regional Government (Granada and Almeria Delegations), and also authorized by the school principals. The study, including the model of informed consent used, was approved by the Ethics Committee of the University of Granada. At the beginning of the study, an informed consent was obtained from the subjects' parents or guardians. This research was performed in strict compliance with the international code of medical ethics established by the World Medical Association and the Declaration of Helsinki. An important condition for inclusion in the study was that subjects had to be healthy and not have any type of endocrine dysfunction or physical disorder. All students who did not meet these criteria were not candidates to participate in the study.

2.2 Anthropometric measurements

Each participant underwent an anthropometric evaluation performed by a Level 2 anthropometrist certified by the International Society for the Advancement of

Kinanthropometry (ISAK), in accordance with the ISAK guidelines [16]. The variables assessed were weight, height, and BMI. We performed the anthropometric measurements in the morning after a 12-hr fast and a 24-hr abstention from exercise. We measured body weight (kg) twice (with participants wearing no shoes and in light clothes) using a self-calibrating Seca 861 class (III) digital floor scale (Saint Paul, USA) with a precision of up to 100 g. We measured height with a Seca 214* portable stadiometer, asking participants to remove their shoes and stand erect with their backs, buttocks, and heels in continuous contact with the vertical height rod of the stadiometer and head oriented in the Frankfurt plane. We then placed the horizontal headpiece on top of the participants' heads to measure their height. We took height measurements twice to the nearest 0.5 cm. We used the average of the two values for weight and height in the analysis. We calculated BMI as weight divided by height squared (kg/m^2). The same trained research assistant performed all the measurements. We defined overweight and obesity, according to the international standards established by Cole et al [17], as values above the 85th and 95th percentiles, respectively, for BMI for age and sex. We measured WC with a Seca automatic roll-up measuring tape (precision of 1 mm) using the horizontal plane midway between the lowest rib and the upper border of the iliac crest at the end of a normal inspiration/expiration. We measured hip circumference at the maximum extension of the buttocks as viewed from the right side. WHR and WHtR were consequently calculated by dividing the WC by the hip circumference and the height, respectively. We also evaluated the triceps, biceps, subscapular, and suprailiac skinfolds with a Holtain® skinfold caliper (Saint Paul, USA), which has a precision of 0.1–0.2 mm and used these measurements to calculate the percentage of body fat. Previously, however, it was necessary to determine body density with Brook's equation [18]. After determining body density, the Siri equation [19] was then used to calculate the body fat percentage.

2.3 Blood Pressure determination

We measured blood pressure (BP) levels using a previously calibrated aneroid sphygmomanometer and a Littmann® stethoscope (Saint Paul, USA). We took all measurements using the right arm after each participant had rested for at least 15 min in a sitting position. We recorded the average of two readings obtained at a minimum of 5 min apart. Systolic BP was based on Korotkoff Phase I and diastolic BP was based on Phase V. Systolic BP $\geq$ 130 and/or diastolic BP $\geq$ 85 mmHg were regarded as a risk factor of MetS.

2.4 Serum Biochemical Examination

At 8:00 A.M. after a 12-hour overnight fast, 10 ml of blood was extracted by venipuncture in the antecubital fossa of the right arm with a disposable vacuum blood collection tube. In the four hours after the extraction, all samples were centrifuged at 1300g for 15 minutes (Z400 K, Hermle, Wehingen, Germany). The red blood cells were thus separated and the serum was finally frozen at -80°C for its subsequent analysis. Immediately after collection and before centrifugation, however, we measured glucose concentration using an enzymatic colorimetric method (glucose oxidase-phenolaminophenazone [GOD-PAP] method, Human Diagnostics, Germany) as well as the concentrations of HDL-C, total cholesterol, and triglycerides by means of enzymatic colorimetric methods using an Olympus analyzer. Low-density lipoprotein-cholesterol (LDL-C) was estimated using the Friedewald equation ($[LDL - C] = [Total\ Cholesterol] - [HDL - C] - ([TG] / 5)$), where TG = concentration of triglycerides. IL-6 and TNF- α were determined by ELISA (Terumpo Corp, Newark, USA; R&D Systems, Minneapolis, USA). hs-CRP was determined by solid-phase chemiluminiscent immunometric assay. Ceruloplasmin was measured by immunoturbidimetry (AU2700 biochemistry analyzer; Olympus). Serum insulin was determined by

radioimmunoanalysis (Insulin Kit, DPC, Los Angeles, EEUU). Insulin resistance was quantified with HOMA (Homeostasis Model Assessment) [20] by applying the following formula: fasting glucose (mmol/L) x fasting insulin (mU/L)/22.5.

2.5 Metabolic syndrome definition

According to the International Diabetes Federation (IDF), Metabolic syndrome (MetS) can be diagnosed in adolescent subjects when the following criteria are fulfilled: a waist circumference ≥ 94 cm in boys and ≥ 80 cm in girls, together with two more risk factors being these ones: fasting blood glucose levels 100–125 mg/dl, serum triglyceride levels ≥ 150 mg/dl, HDL-cholesterol levels < 40 mg/dl in boys and $<$ than 50 mg/dl in girls, and blood pressure $\geq 130/85$ mmHg [21].

2.6 Statistical Analyses

Continuous variables are expressed as mean and SD. Normality was then assessed using the Kolmogorov-Smirnov's test and non-normal variables (CRP, TNF- α , and IL-6) were log transformed to correct for normality. Statistical differences between boys and girls were assessed using the Student's *t*-test. Partial correlations of glucose, triglycerides, total cholesterol, LDL-cholesterol, HDL-cholesterol, insulin, ceruloplasmin, systolic pressure, diastolic pressure and inflammation markers (CRP, IL-6 and TNF- α) were performed after adjusting by age, sex, weight at birth, smoking mother, maternal educational level and maternal obesity. Receiver-operator curves (ROC) were created to determine the predictive value for MetS, the components of MetS (glucose, triglycerides, HDL-cholesterol, systolic pressure and diastolic pressure) and inflammation markers of the different anthropometric

measures used to define obesity (BMI, WHtR, WHR, WC and body fat percentage). The value corresponding to the nearest point of the ROC curve to the top left hand corner was chosen as the optimal threshold for predicting the clustering of factors in that it maximizes both sensitivity and specificity. $AUC > 0.7$ values were considered as predictor factors. Differences were considered significant at $P < .05$. Data were analyzed using SPSS software for Linux version 22.0 (IBM Corp, Amonk, USA).

3. Results

The physical and anthropometric characteristics of all the participants are described in Table 1. Compared to girls, boys had higher values for all anthropometric parameters studied, except for the variable Fat (%), for which girls showed lower values. However, differences in BMI were not statistically significant. Accordingly, no significant differences were found for the percentage of overweight and obese individuals, since this classification was made using BMI. Regarding blood pressure, values were also higher among boys but were only significant for systolic pressure. The prevalence of MetS was significantly higher in girls compared to boys.

Table 2 shows the serum concentrations of biochemical and inflammatory parameters. Boys present higher values compared to the girls for all variables studied but no differences resulted to be non-significant.

As shown in Table 3, of all the anthropometric variables studied, WHR was the only parameter that correlated significantly with all biochemical and inflammatory variables studied in boys. BMI, WHtR, WC and Fat % correlated significantly with plasma insulin levels, systolic and diastolic pressures and ceruloplasmin. These four variables correlated significantly with all anthropometric measures used for obesity assessment in girls.

Tables 4 and 5 show the values obtained from ROC analyses with respect to anthropometric indexes as predictors of MetS, its components and other risk factors in girls and boys, respectively. Both in girls and boys, all anthropometric measures were able to predict MetS, showing AUC values above 0.94, however the fat % classified the girls with MetS only above the 7th decile, whereas for the other measures deciles were 8 or higher. Importantly, in both groups WC was able to predict MetS with a AUC value of 1.00, classifying the subjects in the 9th decile. Cut-off values for MetS were 35, 27, 0.92, 0.56, 94, for Fat %, BMI, WHR, WHtR and WC, respectively in both groups. In addition, all anthropometric measures also showed AUC values above 0.78 for systolic pressure, ceruloplasmin and HOMA also in boys and girls and WHtR and WC showed values of AUC=0.76 for diastolic pressure in boys.

Figure 1 illustrates the contribution of the different anthropometric measures to the prediction of MetS. Colors and individual score values were assigned according to AUC values obtained from ROC curves for the components of the metabolic syndrome only (glucose, triglycerides, systolic pressure, diastolic pressure, HDL-cholesterol and diagnosed metabolic syndrome). Red (value=0): AUC < 0.6, orange (value = 1): AUC=0.60-0.69, yellow (value = 2): AUC=0.70-0.79, light green (value = 3): AUC=0.80-0.89, dark green (value=4): AUC > 0.90. A global score was then calculated as the sum of individual score values. According to this score, WHR was able to predict a higher number of components of MetS, showing a global score value of 9 in both groups studies.

4. Discussion

Being MetS increasingly high among children and adolescents, there is need to find simple but reliable measures to predict its presence. WC together with BMI have been

proposed as predictors of MetS in this population, but the use of these indexes is not supported in other studies. Other proposed measures are WHtR and WHR, which were not able to reach the consensus of the scientific community. Therefore, there is need of studies that assess which anthropometric parameter provides the greatest predictive value for the development of MetS.

In our Spanish sample, we observed that boys had higher values for all the anthropometric parameters studied compared to the girls, except for the variable fat percentage, which was higher among the girls. According to Cousminer et al [22], this higher percentage of body fat could be related to physical and sexual development, which generally occurs earlier in women. This finding is consistent with what was described before [23]. However, there were no significant differences in BMI values between sexes or, consistently, in the prevalence of overweight and obesity, since this classification was based on BMI. As for blood pressure, values were also higher in boys, but were only significant for systolic pressure, in agreement with Androutsos et al [24], who assessed blood pressure in 324 Greek children and adolescents. In this study, the prevalence of MetS was significantly higher in girls compared to boys, which is in contrast to previous studies in which American [25], Iranian [26] and Chinese [27] children were evaluated. These differences could perhaps be explained by the use of different criteria to define the MetS [28,29]. In any case, further studies are needed to explore the possible conditioning factors of these sex-based differences among the pediatric population in general.

On the other hand, among boys, of all the anthropometric variables studied, only WHR correlated significantly with all the biochemical and inflammatory variables studied, suggesting an association between this index and the components that define the MetS in this population. Among girls, BMI, WHtR, WC and Fat % correlated significantly with plasma levels of insulin, systolic and diastolic blood pressure, as well as ceruloplasmin. Likewise,

Rodea-Montero et al [30], in their study on Mexican adolescents, found associations among BMI, WHtR and WC with some components of MetS, highlighting the capacity of WHtR to predict insulin resistance and hypertension in girls. Again, the observed differences between both sexes suggest the influence of sex as a modulating factor against the risk of developing MetS, or to suffer alterations in some of its components.

In relation to the potential predictive capacity for MetS of the anthropometric indexes studied, the ROC analysis showed that in both girls and boys, all measures considered were able to predict MetS, with AUC values above 0.94. However, of all these anthropometric parameters, WHR was the one that was able to predict the highest number of components of MetS. In disagreement with our results, it was previously reported that WHR has a limited predictive capacity against MetS in children [31,32]. Actually, we observed that WC showed the highest predictive value for MetS in both girls and boys (AUC=1.0, cut-off point 94 cm), but not for MetS components. This finding resembles what was described by Kelishadi et al [33], who in a population of 4811 Iranian schoolchildren observed that WC was the anthropometric indicator with greater AUC values and the greatest capacity to predict MetS, compared to other indexes such as WHR or WHtR. Our results partially coincide also with those reported by Ma et al [34] in Chinese adolescents, who propose WC as the indicator with the greatest capacity to predict MetS. In this same line, other studies propose WC and BMI as clinically relevant anthropometric indicators to predict metabolic alterations associated with the early development of MetS in young subjects [35].

The present study has some strengths and limitations. Among the strengths is the large sample size, which contributes to obtaining solid results that will be useful and will improve comparability in future studies. The recruitment was designed to select a representative sample of the entire population for the age groups studied in the region, for which we consider that the study is of great importance in epidemiological terms. In addition, all

participants belonged to the same geographic region, with similar culture, lifestyle and eating habits, making the sample more homogeneous. Among the limitations of the study, we must include its cross-sectional nature.

5. Conclusion

In conclusion, the results show that WHR is the anthropometric index that the greatest number of MetS components predicts, although WC is the anthropometric measure that best predicts the MetS in the population of adolescents studied. These findings may be useful for guidelines of clinical practice and future research on prevention of MetS in adolescent population. Furthermore, these results justify the need to incorporate WHR and WC determinations into daily clinical practice as procedures for predicting the MetS and avoiding its associated complications.

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Figure Legends

Figure 1. Illustration and score of the predictive value for metabolic syndrome and its components of different anthropometric measures of obesity. Colors and score values were assigned according to AUC values obtained from ROC curves. Red (value=0): AUC<0.6, orange (value=1): AUC=0.60-0.69, yellow (value=2): AUC=0.70-0.79, light green (value=3): AUC=0.80-0.89, dark green (value=4): AUC>0.90. Global score was calculated as the sum of individual score values for the components of the metabolic syndrome only (glucose, triglycerides, systolic pressure, diastolic pressure, HDL-cholesterol and diagnosed metabolic syndrome). Fat%: percentage of fat, BMI: body mass index, WHR: waist-to-hip ratio, WHtR: waist-to-height ratio, WC: waist circumference, HOMAIR: homeostatic model assessment of insulin resistance.

439 **Table 1** Physical and anthropometric characteristics according to sex

Variables	Girls (n = 533)	Boys (n = 468)	<i>P</i> value
Weight (kg)	53.0 ± 11.0	56.8 ± 14.2	<.001
Height (cm)	158.0 ± 6.9	162.0 ± 10.7	<.001
BMI (kg/m ²)	21.1 ± 3.6	21.4 ± 4.0	.169
WHtR	0.5 ± 0.1	0.6 ± 0.1	<.001
Waist circumference (cm)	71.2 ± 9.6	73.5 ± 11.9	<.001
Hip circumference (cm)	83.7 ± 8.7	83.9 ± 10.0	.735
WHR	0.9 ± 0.1	0.9 ± 0.1	<.001
Fat (%)	29.6 ± 7.8	27.3 ± 8.2	<.001
SP (mmHg)	116.7 ± 15.1	119.3 ± 15.7	.008
DP (mmHg)	63.9 ± 8.8	64.4 ± 9.2	.382
Overweight (%)	50 (9.4)	53 (11.3)	.385
Obesity (%)	24 (4.5)	23 (4.9)	.536
MetS (%)	98 (18.4)	34 (7.3)	<.001

440 *Values are expressed as means ± SD or n (%). BMI: body mass index; WHtR: waist to height*
441 *ratio; WHR: waist-to-hip ratio; SP: systolic pressure; DP: diastolic pressure; MetS:*
442 *metabolic syndrome.*

455 **Table 2** Serum concentrations of biomarkers according to sex

Variables	Girls (n = 533)	Boys (n = 468)	<i>P</i> value
Glucose (mg/dL)	85.2 ± 28.9	86.2 ± 31.3	.615
Insulin (mIU/L)	20.1 ± 8.9	20.9 ± 10.0	.181
HOMA	4.3 ± 3.1	4.5 ± 2.9	.294
Triglycerides (mg/dL)	124.8 ± 45.9	128.9 ± 58.5	.225
Total Cholesterol (mg/dL)	81.3 ± 15.6	81.7 ± 17.3	.695
LDL-C (mg/dL)	92.9 ± 22.5	93.3 ± 23.6	.771
HDL-C (mg/dL)	40.0 ± 3.1	40.1 ± 2.8	.659
TNF-α (pg/mL)	11.7 ± 2.3	11.9 ± 2.7	.517
IL-6 (pg/mL)	12.76 ± 2.232	12.84 ± 2.616	.895
Ceruloplasmin (mg/dL)	26.79 ± 16.246	27.98 ± 17.879	.270
CRP (mg/dL)	1.12 ± 1.087	1.16 ± 1.171	.636

456 Values are expressed as means ± SD. HOMA: homeostasis model assessment of insulin
 457 resistance; LDL-C: low-density lipoprotein cholesterol; HDL-C: high-density lipoprotein
 458 cholesterol; TNF-α: tumor necrosis factor-alpha; IL-6: interleukin-6; CRP: c-reactive protein.

Table 3 Partial correlation coefficients between components of metabolic syndrome and anthropometric indexes according to sex

	Girls (n = 533)					Boys (n = 468)				
	BMI	WHR	WHtR	Wc	Fat %	BMI	WHR	WHtR	WC	Fat %
Glucose	0.035	0.049	0.037	0.037	0.033	0.110	0.138*	0.033	0.029	0.023
Triglycerides	0.094	0.023	0.057	0.058	0.089*	-0.006	0.163*	0.008	0.007	-0.005
Cholesterol	0.008	0.056	0.007	-0.002	0.019	-0.120	0.110*	0.029	0.012	-0.014
LDL-cholesterol	0.042	0.040	0.035	0.024	0.042	0.051	0.161*	0.084	0.074	0.037
HDL-cholesterol	0.023	-0.035	0.006	0.009	0.009	-0.084	-0.174*	-0.110	-0.095	-0.068
Insulin	0.792*	0.351*	0.702*	0.706*	0.612*	0.815*	0.508*	0.737*	0.744*	0.656*
Sistolic pressure	0.586*	0.233*	0.472*	0.510*	0.464*	0.624*	0.422*	0.549*	0.614*	0.532*
Diastolic pressure	0.431*	0.158*	0.331*	0.370*	0.337*	0.454*	0.290*	0.418*	0.470*	0.411*
CRP	0.035	0.039	0.028	0.028	0.028	0.050	0.155*	0.077	0.066	0.048
IL-6	0.060	0.053	0.057	0.061	0.050	0.038	0.148*	0.068	0.048	0.035
TNF-a	0.034	0.042	0.037	0.042	0.041	0.052	0.141*	0.075	0.064	0.046
Ceruloplasmin	0.764*	0.362*	0.676*	0.689*	0.585*	0.780*	0.504*	0.715*	0.722*	0.635*

Data are adjusted by age, sex, weight at birth, smoking mother, maternal educational level and maternal obesity. *, $P < .05$

Table 4 Area under the receiver operating curve, optimal cutoff value, and sensitivity and specificity for anthropometric indices as predictors of metabolic syndrome in girls

		G	TG	LDL-c	HDL-c	SP	DP	Cp	HOMA	MetS
Fat %	AUC	0.53	0.52	0.52	0.56	0.80*	0.59	0.92*	0.81*	0.95*
	Threshold	28	28	27	27	30	29	31	28	35
	Sensitivity	0.53	0.56	0.55	0.56	0.73	0.67	0.84	0.75	0.88
	Specificity	0.56	0.55	0.54	0.55	0.72	0.59	0.87	0.73	0.84
	Decile	50	50	50	50	60	50	60	50	70
BMI	AUC	0.47	0.44	0.51	0.57	0.86*	0.64	1.00*	0.86*	0.98*
	Threshold	20	20	21	21	23	22	23	22	27
	Sensitivity	0.47	0.44	0.45	0.54	0.78	0.67	1.00	0.78	0.88
	Specificity	0.41	0.42	0.45	0.53	0.79	0.59	1.00	0.81	0.96
	Decile	40	40	40	50	60	60	70	60	80
WHR	AUC	0.58	0.64	0.61	0.6	0.78*	0.6	0.84*	0.79*	0.94*
	Threshold	0.87	0.87	0.87	0.86	0.88	0.89	0.88	0.87	0.92
	Sensitivity	0.59	0.61	0.59	0.59	0.72	0.67	0.74	0.72	0.94
	Specificity	0.58	0.61	0.59	0.59	0.71	0.67	0.74	0.72	0.84
	Decile	60	60	60	50	60	70	60	60	80
WHtR	AUC	0.52	0.52	0.56	0.59	0.82*	0.76	0.92*	0.83*	0.98*
	Threshold	0.44	0.44	0.45	0.45	0.46	0.47	0.46	0.45	0.56
	Sensitivity	0.53	0.56	0.55	0.57	0.76	0.67	0.82	0.75	0.91
	Specificity	0.52	0.50	0.55	0.58	0.75	0.68	0.85	0.76	0.96
	Decile	50	50	60	60	60	70	60	60	90
WC	AUC	0.51	0.5	0.56	0.58	0.87*	0.76	0.93*	0.83*	1.00*
	Threshold	71	73	72	73	77	81	76	75	94
	Sensitivity	0.56	0.56	0.53	0.54	0.8	0.67	0.85	0.75	1.00
	Specificity	0.46	0.53	0.53	0.57	0.80	0.79	0.83	0.73	1.00
	Decile	50	50	50	50	60	70	60	60	90

AUC: area under the curve, WC: waist circumference, BMI: body mass index, WHR: waist-to-hip ratio, WHtR: waist-to-height ratio, SP: systolic pressure, DP: diastolic pressure, Cp: ceruloplasmin, HDL-c: high-density lipoprotein cholesterol, LDL-c: low-density lipoprotein cholesterol, TG: triglyceride, G: glucose, HOMA: homeostasis model assessment of insulin resistance, MetS: metabolic syndrome. *: $P < .05$.

Table 5 Area under the receiver operating curve, optimal cutoff value, and sensitivity and specificity for anthropometric indices as predictors of metabolic syndrome in boys

		G	TG	LDL-c	HDL-c	SP	DP	Cp	HOMA	MetS
Fat %	AUC	0.53	0.52	0.52	0.56	0.80*	0.59	0.92*	0.81*	0.95*
	Threshold	28	28	27	27	30	29	31	28	35
	Sensitivity	0.53	0.56	0.55	0.56	0.73	0.67	0.84	0.75	0.88
	Specificity	0.56	0.55	0.54	0.55	0.72	0.59	0.87	0.73	0.84
	Decile	50	50	50	50	60	50	60	50	70
BMI	AUC	0.47	0.44	0.51	0.57	0.86*	0.64	1.00*	0.86*	0.98*
	Threshold	20	20	21	21	23	22	23	22	27
	Sensitivity	0.47	0.44	0.45	0.54	0.78	0.67	1.00	0.78	0.88
	Specificity	0.41	0.42	0.45	0.53	0.79	0.59	1.00	0.81	0.96
	Decile	40	40	40	50	60	60	70	60	80
WHR	AUC	0.58	0.64	0.61	0.60	0.78*	0.60	0.84*	0.79*	0.94*
	Threshold	0.87	0.87	0.87	0.86	0.88	0.89	0.88	0.87	0.92
	Sensitivity	0.59	0.61	0.59	0.59	0.72	0.67	0.74	0.72	0.94
	Specificity	0.58	0.61	0.59	0.59	0.71	0.67	0.74	0.72	0.84
	Decile	60	60	60	50	60	70	60	60	80
WHtR	AUC	0.52	0.52	0.56	0.59	0.82*	0.76*	0.92*	0.83*	0.98*
	Threshold	0.44	0.44	0.45	0.45	0.46	0.47	0.46	0.45	0.56
	Sensitivity	0.53	0.56	0.55	0.57	0.76	0.67	0.82	0.75	0.91
	Specificity	0.52	0.50	0.55	0.58	0.75	0.68	0.85	0.76	0.96
	Decile	50	50	60	60	60	70	60	60	90
WC	AUC	0.51	0.5	0.56	0.58	0.87*	0.76*	0.93*	0.83*	1.00*
	Threshold	71	73	72	73	77	81	76	75	94
	Sensitivity	0.56	0.56	0.53	0.54	0.8	0.67	0.85	0.75	1.00
	Specificity	0.46	0.53	0.53	0.57	0.80	0.79	0.83	0.73	1.00
	Decile	50	50	50	50	60	70	60	60	90

AUC: area under the curve, WC: waist circumference, BMI: body mass index, WHR: waist-to-hip ratio, WHtR: waist-to-height ratio, SP: systolic pressure, DP: diastolic pressure, Cp: ceruloplasmin, HDL-c: high-density lipoprotein cholesterol, LDL-c: low-density lipoprotein cholesterol, TG: triglyceride, G: glucose, HOMA: homeostasis model assessment of insulin resistance, MetS: metabolic syndrome. *: $P < .05$.

Girls

	Fat %	BMI	WHR	WHtR	WC
Glucose					
Triglycerides					
LDL-cholesterol					
HDL-cholesterol					
Systolic pressure					
Diastolic pressure					
Ceruloplasmin					
HOMAIR					
Metabolic Syndrome					
Score	5	6	9	5	5

Boys

	Fat %	BMI	WHR	WHtR	WC
Glucose					
Triglycerides					
LDL-cholesterol					
HDL-cholesterol					
Systolic pressure					
Diastolic pressure					
Ceruloplasmin					
HOMAIR					
Metabolic Syndrome					
Score	6	6	9	8	8

Highlights

- Metabolic syndrome (MetS) is increasing in adolescents.
- There is need of early easy-to-use predictors of MetS using anthropometric indexes.
- Waist circumference predicts MetS with the highest level of certainty.
- Waist-to-hip ratio is helpful to predict the presence of the components of MetS.