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Association of anthropometric indices with cardiovascular disease risk factors among children and adolescents: CASPIAN Study

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Abstract

Background: For the first time in Iran, and to the best of our knowledge in Asia, we assessed the anthropometric indices most closely correlated to cardiovascular disease (CVD) risk factors in a large nationally representative sample of children and adolescents to be used as a simple tool for identifying those at risk.

Methods: This multi-center study was performed among a representative sample of 4811 school students (2248 boys and 2563 girls) aged 6–18 years, as part of the baseline survey of a national surveillance system. Anthropometric indices and CVD risk factors were measured using standard protocols, and their correlation was analyzed by using Receiver Operator Characteristic (ROC) curves and partial correlation.

Results: The most prevalent CVD risk factors were low HDL-C (28%), followed by hypertriglyceridemia (20.1%), and overweight (17%). The ROC analyses showed that among boys, all anthropometric indices had the same association with CVD risk factors in 6–9.9-year-age group, while in the 10–13.9 and 14–18-year-age groups, respectively waist circumference (WC) and body mass index (BMI) were the best in distinguishing CVD risk factors. Among girls, these indices were respectively BMI and waist to stature ratio (WSR); WC and WSR; and WC. In the partial correlation analysis, in boys, the highest coefficient was found for BMI; BMI and WC; and for WC and WSR; in girls, these indices were BMI; WC and WSR; and BMI respectively.

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Conclusions: In the present study, BMI, WC and WSR were the most appropriate in predicting CVD risk factors. It may be clinically useful in the pediatric population to routinely measure WC and WSR in addition to BMI as a screening tool to identify high-risk youth.

Keywords: Anthropometric index; Children and adolescents; Cardiovascular disease risk factors; Sensitivity; Specificity

1. Introduction

It is widely agreed that chronic diseases are escalating much more rapidly in developing than industrialized countries [1]. Underlying genetic tendency or early-life adverse events may contribute to the metabolic syndrome and adverse body fat-patterning including abdominal adiposity and its related complications in non-European populations [2].

Interest in childhood precursors to chronic diseases notably cardiovascular disease (CVD) is increasing because it is well documented that both behavioral and biological risk factors of such diseases persist from childhood into adulthood [3], and that several risk factors including overweight, dyslipidemia and high blood pressure are tracked from childhood to adult life, and are linked to adult diseases [4,5].

Consequently, a potential emerging public health crisis may be the increasing incidence of childhood overweight and adverse body fat-patterning including abdominal adiposity and, as a result, new cases of children with the metabolic syndrome (MetS), that is a key feature of the pathogenesis of type2 diabetes, and the progression of CVDs, which in turn is likely to create an enormous socioeconomic and public health burden in the near future [6–8].

The growing prevalence of childhood obesity highlights the need to identify high-risk children for targeted interventions. Usually for clinical practice and epidemiological studies, child overweight and obesity is assessed by indicators based on weight and height measurements, such as body mass index (BMI); however, this index cannot distinguish fat from muscle mass, nor can it represent the fat distribution. This overall obesity index may not be the most appropriate in predicting CVDs [9].

Studies among adults indicated that the Asian populations are predisposed to visceral or abdominal obesity [10,11]. Population-based studies concerning the correlation of anthropometric indices and the risk factors of CVD in youths, although limited, have documented that in children, as in adults, abdominal or upper body fat carries an increased risk for metabolic complications such as dyslipidemia, and high fasting glucose, as well as for high blood pressure [12,13]. A recent study confirmed that similar to adults, a clustering of metabolic abnormalities occur in those adolescents with the hypertriglyceridemic phenotype [14].

Obtaining information on anthropometric indices related to CVD risk factors in children and adolescents could be useful as a means of identifying not only the overweight in children population studies, but also the abdominal fat deposition that is found to be related to chronic diseases later in life [15]. In adults, the waist circumference (WC) correlates well with intra-abdominal fat mass and has proved to be an independent risk for obesity-related diseases [16,17]. Visceral adipose tissue (VAT) is shown to be associated with many risk factors for chronic diseases, and during the last decade it has been evaluated by Magnetic Resonance Imaging (MRI) in children; and it is found to be related to glucose metabolism, lipids abnormalities and hypertension. However, as MRI is a difficult and expensive method, the relationship between anthropometry and VAT are being studied among children. A recent study confirmed the relationship between WC and MRI derived VAT among children; however this association has been influenced by ethnicity, gender and pubertal stage [18].

Considering the ethnic differences between the body size, and the pattern of fat deposition among Asians and Western communities, some researchers have assessed other anthropometric indices as waist-to-hip ratio (WHR) and waist-to-stature ratio (WSR) in children [19].

Similar to many other developing countries, the epidemiologic transition along with rapid lifestyle changes made Iranian youth prone to CVD risk factors and as a result, to chronic diseases later in life [20–22]. Consequently, for the first time in Iran, and to best of our knowledge in Asia, we determined the anthropometric index most closely correlated to CVD risk factors in a large nationally representative sample of children and adolescents to be used as a simple tool for identifying those at risk.

2. Methods

This study was performed as part of the baseline survey of a longitudinal national project entitled: "*C*hildhood & *A*dolescence *S*urveillance and *P*revent*I*on of *A*dult *N*on-communicable disease": *CASPIAN*[1] Study. The first phase of this multi-center study was conducted at national level in 2003–2004 among 21,111 school students (96% participation rates) living in urban and rural areas of the central cities of 23 (out of 28) provinces, as a joint collaboration of the World Health Organization (WHO/EMRO) and the National Ministry of Health (MoH) and Ministry of Education (MoE). The present paper describes the findings obtained

[1] Caspian is the name of the world's largest lake, located in Northern Iran.

from a sub-sample of 4811 school students selected from 6 provinces located in diverse parts of the country (91% participation rate). In these counties, biochemical variables were examined in addition to the risk behaviors and biological risk factors evaluated in the whole subjects studied.

Ethics committees and other relevant national regulatory organizations approved the study. Written informed consent was obtained from parents and oral assent from students, Subjects were selected by multistage-random cluster sampling. Schools were stratified according to location (urban/rural), and the socioeconomic character of its uptake area, with consideration of the proportion of the different types of schools (public/private) in order to avoid socio-economic bias. From each stratum, a proportional, two-stage cluster sample of students was selected. The primary units (clusters) were the schools. The secondary units were the students within the schools. Students were allocated code numbers and randomly selected using random number tables.

The field examinations of the survey were carried out by a team consisting of expert health care professionals specially trained for the survey. The questionnaires were filled out confidentially under the supervision of trained nurses. The age and birth date of subjects were recorded. Height (Ht) and weight (Wt) were measured twice to ±0.2 cm and to ±0.2 kg, respectively, with subjects being barefoot and lightly dressed; the averages of these measurements were recorded. Body mass index (BMI) (weight in kilograms divided by the square of height in meters) was calculated. Waist circumference (WC) was measured with a non-elastic tape at a point midway between the lower border of the rib cage and the iliac crest at the end of normal expiration. Hip circumference (HiC) was measured at the widest part of the hip at the level of the greater trochanter to the nearest half-centimeter [23]. Next, waist-to-hip ratio (WHR) and the waist-to-stature ratio (WSR) were computed by dividing the WC by the HiC and Ht, respectively.

Blood pressure (BP) was measured using mercury sphygmomanometers after 5 min of rest in the sitting position. The subjects were seated with the heart, cuff, and zero-indicator on the manometer at the level of the observer's eye. All readings were taken in duplicate in the right arm. Appropriate size cuffs were used with cuff-width 40% of mid-arm circumference, and cuff bladders covering 80% to 100% of the arm circumference and approximately two thirds of the length of the upper arm without overlapping. The procedure was explained to the students and the cuff inflated and deflated once, the first BP measured was not used in the analysis of this study. The readings at the first and the fifth Korotkoff phase were taken as systolic and diastolic BP (SBP and DBP), respectively. The average of the two BP measurements was recorded and included in the analysis [24].

For blood sampling, students were invited to the nearest health center to the school, in accordance with the rules of the national MoE. The students were instructed to fast for 12 h before the screening; compliance with fasting was determined by interview on the morning of examination. While one of parents accompanied his/her child, blood samples were taken from the antecubital vein between 8:00 and 9:30 am. After collecting blood samples, the participants were served a healthy snack provided by the project team.

The blood samples were centrifuged for 10 min at 3000 rpm within 30 min of venipuncture. In each county, the biochemical analysis was performed in the Central Provincial laboratory which met the standards of the National Reference laboratory, a WHO-collaborating center in Tehran. Fasting blood sugar (FBS), total cholesterol (TC), high density lipoprotein-cholesterol (HDL-C) and triglyceride (TG) were measured enzymatically by auto-analyzers. HDL-C was determined after dextran sulphate-magnesium chloride precipitation of non-HDL-C [25,26]. Low-density lipoprotein-cholesterol (LDL-C) was calculated in serum samples with TG ≤ 400 mg/dl according to the Friedwald equation [27]. A sub-sample of sera was frozen and transported from different counties to the central laboratory at Isfahan Cardiovascular Research Center (WHO-Collaborating Center), which meets the standards of the National Reference laboratory and is also under the quality control of the Department of Epidemiology, St. Rafael University, Leuven, Belgium. In addition, a sub-sample of frozen sera was stored at −70 °C for future biochemical analyses for new risk factors.

Considering that collecting data of high quality was critical to the success of our multi-center project, the Data and Safety Monitoring Board (DSMB) of the project has taken in account different levels of quality assurance and quality control (QA/QC). A supervisor and a team of external evaluators nominated by the two collaborating ministries, which regularly monitored the performance of the personnel, checked and calibrated equipment according to standardized protocols. Repeat studies were designed and conducted at specified time points on a sub-sample of the students studied. These repeat studies required taking multiple measurements on the same participant in order to quantify variability and to identify its sources, as well as to implement corrective action as appropriate in a timely manner to minimize measurement errors. The data entry staff entered data for all forms and questionnaires twice and checked for completeness and inconsistencies.

Definition of risk factors: The BMI percentiles provided by the Centers for Disease Control and Prevention (CDC) were used for the classification of the children and adolescents as underweight, normal, overweight and obese [28]. Abnormal serum lipids were defined as a TC, LDL-C and or TG higher than the level corresponding to the age and gender specific 95th percentile, as well as HDL-C lower than age and gender specific 5th percentile [29]. FBS levels equal or more than 100 mg/dl were considered high [30]. Elevated

BP was defined as the mean SBP or DBP above the 90th percentile for that age and gender after adjusting for weight and height [24].

Data analysis: After editing, we transferred the data by the Stat Transfer 7 software to the SPSS version 13.0 software (SPSS, Inc. Chicago, IL). The subjects' biological and biochemical variables were compared by analysis of variance (ANOVA) and Tukey Post Hoc tests. In order to determine the best anthropometric index associated with CVD risk factors, two statistical methods were used. First Receiver Operator Characteristic (ROC) curve analyses were used to calculate the area under ROC curves between each CVD risk factor and anthropometric index. Each value of an anthropometric index was used as a cutoff value to calculate its sensitivity and specificity in classifying a CVD risk factor. The ROC curve is a plot of the sensitivity against specificity for each cutoff value, and the area under curve (AUC) is an indicator of how good the anthropometric indices can distinguish a positive test outcome. AUC ranges from 0 to 1, with 0.5 (diagonal line) indicating that the anthropometric index has no predictive power and 1 indicating perfect power. After determining the best anthropometric index, the optimal cutoff value was denoted by the value that had the largest sum of sensitivity and specificity [31,32]. In addition, partial correlation analysis was performed between CVD risk factors and anthropometric indices. The statistical significance was set at $p<0.05$.

3. Results

The subjects studied in this multi-center study included 2248 boys and 2563 girls, aged 6–18 years. Boys had higher mean levels of Wt, Ht, BMI, WC, WHR and WSR, as well as SBP and DBP than girls; other variables were not significantly different in terms of gender. Other than HDL-C, all variables studied increased significantly with increasing age (Table 1).

Table 2 presents the prevalence of different CVD risk factors studied according to gender, living area and age group. Overweight, high TC, high LDL-C and high TG were significantly more prevalent in girls than in boys; and high FBS as well as high SBP/DBP were more prevalent in boys than in girls. The prevalence of overweight, high TC, low HDL-C, and high TG was significantly higher in urban than in rural residents. The prevalence of high LDL-C, low HDL-C, and high TG was significantly lower in the 10–13.9-year-old subjects than the two other age groups studied.

The age-adjusted correlation between the anthropometric indices was significant in both genders. BMI and WC had the highest correlation ($r=0.7$, $p<0.0001$ in boys, and $r=0.8$, $p<0.0001$ in girls). The weakest correlation was found between BMI and WSR ($r=0.5$, $p<0.0001$ in boys, and $r=0.6$, $p<0.0001$ in girls).

The ROC curves of the four anthropometric indices in relation to one or more risk factors according to gender and age group are depicted in Fig. 1. It shows that among boys, the AUC of all anthropometric indices was the largest in 6–9.9-year-old students. The AUC of WC was the largest in

Table 1
Descriptive characteristics (mean±S.D.) of subjects studied according to gender and age group: CASPIAN Study

	6–9.9 years	10–13.9 years	14–18 years	Total
Boys				
n	757	842	649	2248¶
Age	8.2 (1.3)	12.4 (1.1)	16.1 (1.0)	12.1 (3.3)¶
BMI	16.4 (3.0)	18.4 (3.7)	20.4 (3.4)	18.3 (3.7)¶
WC	58.5 (7.2)	67.6 (9.7)	72.6 (8.9)	66.0 (10.4)¶
HiC	70.4 (7.4)	83.2 (9.4)	90.0 (9.1)	80.8 (11.8)¶
WHR	83.2 (5.7)	81.3 (8.6)	80.7 (7.1)	81.8 (7.4)¶
WSR	44.6 (4.6)	43.5 (5.5)	42.5 (4.8)	43.6 (5.1)¶
SBP	96.1 (12.5)	102.7 (12.7)	111.8 (12.8)	103.1 (14.1)¶
DBP	59.4 (10.2)	62.8 (10.2)	71.9 (9.9)	64.3 (11.3)¶
LDL-C	88.9 (30.0)	87.3 (29.8)	77.2 (29.0)	84.9 (30.1)¶
HDL-C	43.7 (12.5)	45.4 (11.9)	43.7 (11.9)	44.3 (12.1)¶
TC	150.7 (32.1)	153.9 (38.1)	139.7 (31.5)	148.7 (34.8)¶
TG	91.0 (43.7)	98.9 (61.5)	95.5 (46.1)	95.3 (51.8)
FBS	82.2 (11.2)	82.1 (12.0)	80.1 (12.2)	81.6 (11.8)¶
Girls				
n	859	1045	659	2563¶
Age	8.2 (1.3)	12.5 (1.1)	16.1 (1.0)	12.0 (3.2)¶
BMI	16.1 (2.8)	19.4 (3.6)	21.1 (3.7)	18.7 (3.9)¶
WC	56.9 (7.1)	66.6 (8.7)	70.0 (8.4)	64.2 (9.7)¶
HiC	70.2 (7.9)	84.7 (9.3)	91.1 (8.2)	81.5 (12.0)¶
WHR	81.2 (5.2)	78.7 (6.8)	76.8 (5.8)	79.0 (6.3)¶
WSR	43.2 (4.3)	43.1 (5.2)	43.7 (5.1)	43.3 (4.9)
SBP	92.5 (11.4)	99.5 (12.3)	102.7 (12.9)	98.0 (12.8)¶
DBP	57.4 (10.3)	62.4 (10.1)	64.1 (9.9)	61.2 (10.5)¶
LDL-C	88.4 (33.0)	86.5 (28.3)	80.7 (28.3)	85.7 (30.1)¶
HDL-C	44.1 (12.0)	43.4 (12.3)	45.7 (14.2)	44.2 (12.7)¶
TC	150.1 (35.5)	150.4 (30.9)	144.8 (32.9)	148.9 (33.1)¶
TG	91.4 (43.7)	103.6 (51.2)	94.6 (45.9)	97.2 (47.8)¶
FBS	80.2 (10.0)	81.2 (9.4)	79.8 (9.1)	80.5 (9.6)¶
Total				
n	1616	1887	1308	4811
Age	8.2 (1.3)	12.5 (1.1)	16.1 (1.0)	12.0 (3.2)¶
BMI	16.2 (2.9)	19.0 (3.7)**	20.8 (3.5)**	18.5 (3.8)**¶
WC	57.7 (7.2)**	67.0 (9.2)*	71.3 (8.8)**	65.0 (10.1)**¶
HiC	70.3 (7.7)	84.1 (9.4)**	90.6 (8.6)*	81.2 (11.9)¶
WHR	82.1 (5.5)**	79.8 (7.7)**	78.8 (6.8)**	80.3 (6.9)**¶
WSR	43.9 (4.5)**	43.3 (5.3)	43.1 (5.0)**	43.4 (5.0)*¶
SBP	94.2 (12.1)**	101.0 (12.6)**	107.2 (13.6)**	100.4 (13.7)**¶
DBP	58.4 (10.3)**	62.6 (10.2)	68.0 (10.6)**	62.6 (11.0)**¶
LDL-C	88.6 (31.6)	86.9 (29.0)	78.9 (28.7)*	85.3 (30.1)¶
HDL-C	43.9 (12.2)	44.3 (12.2)**	44.7 (13.2)**	44.3 (12.5)
TC	150.4 (34.0)	152.0 (34.3)*	142.2 (32.3)**	148.8 (33.9)¶
TG	91.2 (43.7)	101.5 (56.1)	95.1 (46.0)	96.3 (49.7)¶
FBS	81.1 (10.6)**	81.6 (10.7)	79.9 (10.8)	81.0 (10.7)**¶

*Significant at $p<0.05$ between genders, **Significant at $p<0.01$ between genders, ¶Significant at $p<0.01$ between age groups (by ANOVA and Tukey Post Hoc tests).

BMI: body mass index (kg/m^2), WC: waist circumference (cm), HiC: hip circumference (cm), WHR: Waist-to-hip ratio, WSR: waist-to-stature ratio, SBP: systolic blood pressure (mm Hg), DBP: diastolic blood pressure (mm Hg), TC: total cholesterol (mg/dl), LDL-C: low-density cholesterol (mg/dl), HDL-C: high-density cholesterol (mg/dl), TG: triglyceride (mg/dl), FBS: fasting blood sugar (mg/dl).

Table 2
Prevalence (%) of different cardiovascular disease risk factors according to gender, age group and living area: CASPIAN Study

	Boys (n=2248)			Girls (n=2563)			Total (n=4811)		
	Urban (94.5%)	Rural (5.5%)	Total	Urban (93.84%)	Rural (6.16%)	Total	Urban (94.1%)	Rural (5.9%)	Total
Prevalence (%) of high BMI									
6–9.9 years	18.1	15.2**	17.2	15.1	15.0	15.1	17.2	15.1	16.1
10–13.9 years	15.1	5.2	13.5	19.1	19.1	20.1	19.0	17.1	17.2
14–18 years	14.2	14.1	14.2	18.2	18.2	20.0	17.1	17.2	17.1
Total	17.1	14.2	15.1*	18.2	17.1	18.2*	18.2¶	17.2¶	17.0
Prevalence (%) of high TC									
6–9.9 years	4.2	3.1	4.1	7.1	6.3	7.0	6.3	6.1	6.2
10–13.9 years	6.1	7.0	6.2	5.2	3.2	5.1	5.4	4.1	5.2
14–18 years	3.2	4.1	3.2	5.1	5.2	5.1	4.1	2.5	4.1
Total	7.0	4.5	4.2*	6.2	9.1	6.2*	7.2¶	5.1¶	5.4
Prevalence (%) of high LDL-C									
6–9.9 years	9.1	7.2	9.1	14.2	6.4	12.4	11.1	7.2	11.0
10–13.9 years	9.2	7.0	9.1	7.2	5.3	8.2	8.4	7.1	8.1
14–18 years	4.2	2.8	4.2	5.2	4.4	5.1	5.2	4.5	5.1
Total	7.1	7.0	7.0*	9.3	7.1	9.1*	8.7	6.9	8.2†
Prevalence (%) of low HDL-C									
6–9.9 years	32.1	10.2	31.0	31.1	19.2	31.0	31.2	15.2	31.0
10–13.9 years	28.1	18.0	27.1	37.0	21.1	36.0	33.1	19.2	32.1
14–18 years	24.0	22.0	22.3	18.2	15.4	17.1	20.2	19.1	20.1
Total	27.2	24.1	27.0	29.1	13.1	28.2	28.1¶	18.2¶	28.0†
Prevalence (%) of high TG									
6–9.9 years	27.1	21.2	22.4	25.1	23.1	25.0	24.3	21.9	24.1
10–13.9 years	20.0	19.2	19.1	24.4	21.2	23.2	21.6	20.4	21.2
14–18 years	15.4	4.3	15.1	16.4	15.2	16.1	15.2	14.6	15.1
Total	21.2	19.8	19.2*	24.1	19.0	22.0*	20.4¶	19.6¶	20.1†
Prevalence (%) of high FBS									
6–9.9 years	1.8	0.4	1.1	1.8	0.2	1.0	1.2	0.1	1.1
10–13.9 years	5.3	3.8	5.0	4.4	3.1	4.1	4.5	1.2	4.1
14–18 years	4.3	2.7	4.2	3.4	1.7	3.1	3.8	0.2	3.2
Total	5.4	3.9	5.1*	3.5	1.3	3.0*	4.1	0.9	4.1†
Prevalence (%) of high SBP/DBP									
6–9.9 years	5.7	4.8	5.1	7.7	6.4	7.1	9.3	8.9	9.1
10–13.9 years	6.8	5.2	6.3	4.5	2.9	4.1	5.4	4.1	5.2
14–18 years	8.2	7.7	8.1	3.4	2.8	3.2	9.1	6.8	8.1
Total	7.4	6.9	7.2*	5.7	5.2	5.4*	8.7	7.1	7.4†

*$p<0.05$ between genders; **$p<0.0001$ between urban and rural residents; ¶$p<0.05$ between urban and rural residents; †$p<0.05$ between age groups.
High BMI: body mass index ≥ 85th age and gender-specific percentile, high TC: total cholesterol ≥ 95th age and gender-specific percentile, high LDL-C: low-density cholesterol > 95th age and gender-specific percentile, low HDL-C: high-density cholesterol ≤ 5th age and gender-specific percentile, high TG: triglyceride ≥ 95th age and gender-specific percentile, high FBS: fasting blood sugar > 100 mg/dl, high SBP: systolic blood pressure ≥ 90th age and gender-specific percentile, high DBP: diastolic blood pressure ≥ 90th age and gender-specific percentile, high SBP/DBP: systolic/diastolic blood pressure ≥ 90th age and gender-specific percentile.

subjects aged 10–13.9 years, and that of BMI was the largest in the 14–18-year-age group. Among girls, these indices were respectively BMI and waist-to-stature ratio (WSR); WC and WSR; and WC.

Table 3 presents the optimal cutoff values, as well as the sensitivity and the specificity of the anthropometric indices in relation to each CVD risk factor in boys according to the age group. Overall, the cutoff values in boys ranged from 13.9 to 22.04 for BMI, 45.5 to 79.5 for WC, 0.7 to 0.9 for WHR and 0.3 to 0.4 for WSR. Among girls, they ranged from 15.5 to 21.4 for BMI, 48.5 to 76.5 for WC, 0.75 to 0.86 for WHR and 0.40 to 0.48 for WSR (Table 4).

The partial correlation between anthropometric indices and CVD risk factors showed that among boys, BMI had the highest coefficient in 5 risk factors among 6–9.9 years subjects (r=0.07–0.2); in the 10–13.9 years age group, BMI and WC had the highest coefficient in 4 risk factors, and in 14–18-year-old subjects, WC and WSR had the highest coefficient in 3 risk factors (−0.06–0.3). In girls, BMI had the highest coefficient in 4 risk factors in

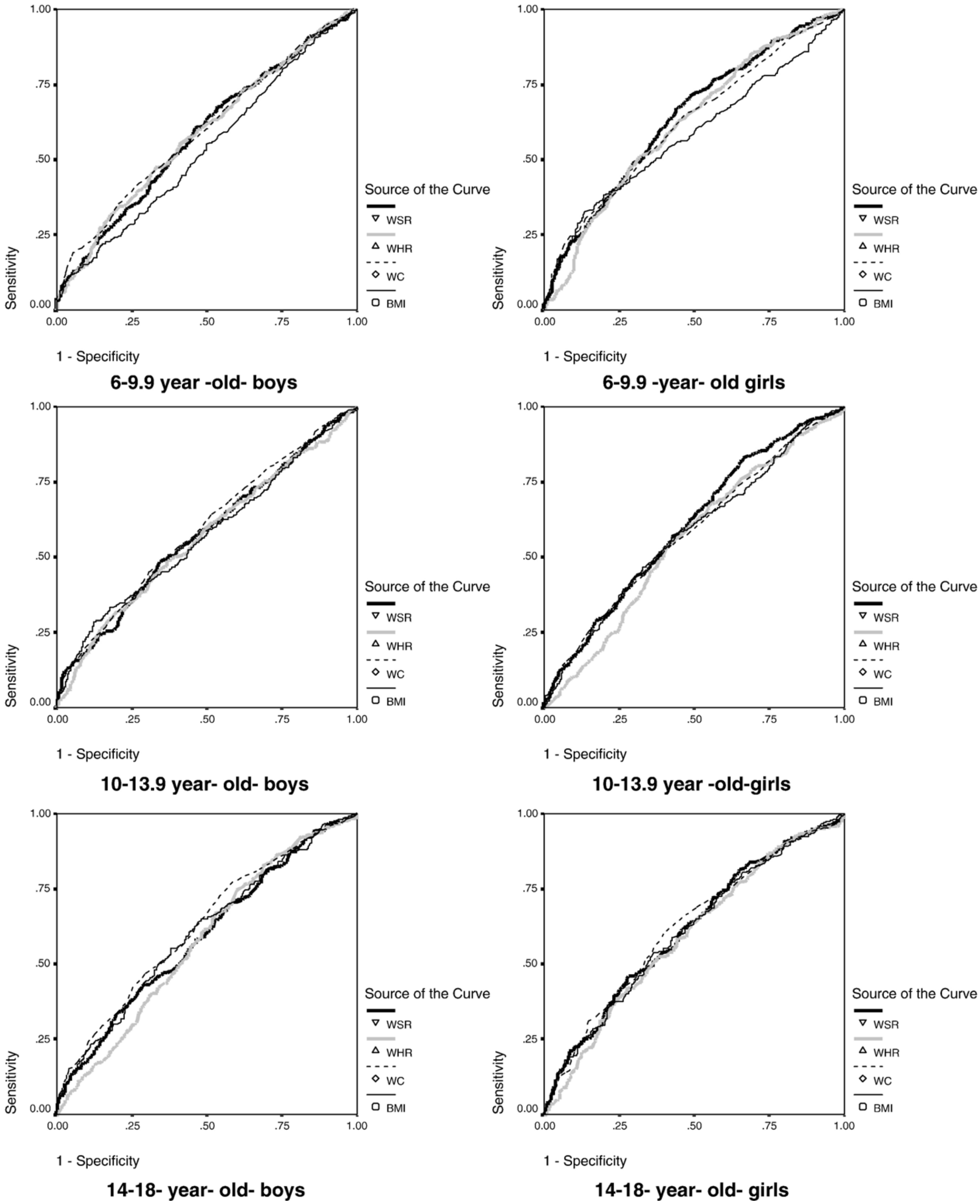

Fig. 1. Receiver operating characteristic (ROC) curves for one or more risk factors according to gender and school level: CASPIAN Study. BMI: body mass index, WC: waist circumference, WHR: waist-to-hip ratio, WSR: waist-to-stature ratio.

subjects aged 6–9.9 years (r=0.05–0.3); in the 10–13.9-year-age group, WC and WSR had the highest coefficient in 3 risk factors (r=−0.2–0.2), and in the 14–18-year-old subjects, BMI had the highest coefficient in 4 risk factors (r=0.03–0.2).

4. Discussion

Contrary to studies among adults that determined a single anthropometric parameter as the best predictive index for CVD risk factors, in our study, this index varied well

Table 3
Optimal cutoff values[a], sensitivity (Se) and specificity (Sp) of anthropometric indices for cardiovascular risk factors in boys: CASPIAN Study

School level	Risk factors	BMI			WC			WHR			WSR		
		Cutoff	Se	Sp	Cutoff	Se	Sp	Cutoff	Se	Sp	Cutoff	Se	Sp
6–9.9 years	High TC	19.4	0.5	0.8	65.5	0.5	0.8	0.8	0.4	0.7	0.4	0.4	0.8
	High LDL-C	16.7	0.4	0.7	60.5	0.4	0.7	0.8	0.4	0.7	0.4	0.6	0.5
	Low HDL-C	13.9	0.9	0.1	55.5	0.7	0.3	0.8	0.6	0.5	0.4	0.6	0.5
	High TG	18.3	0.3	0.8	60.5	0.4	0.7	0.8	0.6	0.4	0.4	0.7	0.3
	High FBS	12.3	1.0	0.02	45.5	1.0	0.01	0.7	1.0	0.1	0.4	0.9	0.1
	High SBP/DBP	16.0	0.6	0.5	62.5	0.4	0.7	0.8	0.5	0.7	0.4	0.6	0.5
10–13.9 years	High TC	21.0	0.5	0.8	66.5	0.6	0.5	0.7	0.7	0.4	0.4	0.7	0.5
	High LDL-C	21.4	0.2	0.8	72.5	0.3	0.7	0.7	0.7	0.4	0.4	0.6	0.5
	Low HDL-C	21.2	0.2	0.8	62.5	0.7	0.3	0.8	0.6	0.4	0.3	0.8	0.2
	High TG	19.6	0.5	0.7	68.5	0.5	0.6	0.8	0.4	0.6	0.4	0.5	0.6
	High FBS	21.3	0.5	0.8	70.5	0.6	0.7	0.8	0.9	0.5	0.4	0.7	0.5
	High SBP/DBP	18.7	0.7	0.6	69.5	0.7	0.6	0.8	0.3	0.8	0.4	0.7	0.5
14–18 years	High TC	20.4	0.6	0.6	74.5	0.5	0.6	0.8	0.3	0.8	0.4	0.5	0.7
	High LDL-C	21.4	0.5	0.7	73.5	0.6	0.6	0.7	0.6	0.4	0.4	0.5	0.7
	Low HDL-C	20.0	0.5	0.5	69.5	0.7	0.4	0.7	0.9	0.2	0.3	0.8	0.2
	High TG	21.4	0.5	0.7	73.5	0.5	0.6	0.8	0.4	0.7	0.4	0.5	0.7
	High FBS	21.4	0.6	0.7	71.5	0.7	0.5	0.9	0.5	0.9	0.4	0.6	0.5
	High SBP/DBP	21.9	0.4	0.8	76.5	0.4	0.7	0.8	0.5	0.7	0.4	0.4	0.7

BMI: body mass index (kg/m^{2}), WC: waist circumference (cm), WHR: waist-to-hip ratio, WSR: waist-to-stature ratio, high TC: total cholesterol ≥ 95th age and gender-specific percentile, high LDL-C: low-density cholesterol ≥ 95th age and gender-specific percentile, low HDL-C: high-density cholesterol ≤ 5th age and gender-specific percentile, high TG: triglyceride ≥ 95th age and gender-specific percentile, high FBS: fasting blood sugar > 100 mg/dl, high SBP/DBP: systolic/diastolic blood pressure ≥ 90th age and gender-specific percentile.
[a] The optimal cutoff value was denoted by the value that had the largest sum of sensitivity and specificity.

according to gender and age group. Among boys, in subjects aged 6–9.9 years, all anthropometric indices had similar predictive value while in the 10–13.9 and 14–18-year-age groups, respectively WC and BMI; and among girls, BMI and WSR; WC and WSR; and WC were the best in distinguishing CVD risk factors, respectively. Although the best anthropometric indices were identified, it should be noted that the differences for the anthropometric indices were often small with overlapping confidence intervals.

Most previous studies have determined the correlation of different anthropometric indices with CVD risk factors among adults. Some studies performed in South Asian adult population found WSR as the best anthropometric parameter. For instance, the study of Pua and Ong [33] among Singaporean women, and the study of Ho et al. [34] in Hong Kong Chinese found that WSR might be the best anthropometric index in relation to CVD risk factors. A recent study in Japan showed that WSR is more sensitive than BMI or WC to evaluate clustering of coronary risk factors among non-obese men and women [35]. But some studies in Western countries found that other anthropometric parameters have better correlation with CVD risk factors than WSR has. The study of Ledoux et al. among Canadians revealed that WC and BMI correlate most closely with blood pressure and plasma lipids [36]. In the study of Zhu et al. among Americans of three race–ethnicity groups, WC was more sensitive than BMI in predicting CVD risk [37].

Population-based studies concerning the correlation of anthropometric indices and CVD risk factors in children and adolescents are limited, and comprise different age groups making the comparisons difficult. The recent study of Kahn and Cheng among a population drawn from the third National Health and Nutrition Examination Survey (NHANES III) in the US showed that WHR is a simpler anthropometric index than sex- and age-specific BMI percentiles, and better identifies youth with adverse CVD risk factors [38]. In Cyprus, Savva et al. found that in children (with a mean age of 11.4 years), WC and WSR are better predictors of CVD risk factors than BMI [39]. The study of Maffeis et al. in Italy showed that WC, as well as subscapular and triceps skin folds, may be helpful parameters in identifying prepubertal children with dyslipidemia and high blood pressure [40]. In Portugal, Teixeira et al. showed that among 159 children with a mean age of 13 years, measures of central adiposity such as WC and WSR significantly correlated with serum lipid levels in obese children and adolescents but not in leaner individuals [41]. Similar to studies performed among adults in Japan, the study of Hara et al. showed that WSR is the best predictor of CVD risk factors in Japanese school children with 9–13 years of age [42]. The study of Asayama et al. among obese Japanese girls confirmed such correlation, and found that only WSR/Ht showed high enough sensitivity and specificity to predict CVD risk factors [43].

Usually for clinical practice and epidemiological studies, child overweight and obesity is assessed by indicators such as BMI. The present study documented BMI as a predictor of CVD risk factors in children and adolescents; this finding is consistent with previous studies confirming the predictive

Table 4
Optimal cutoff values[a], sensitivity (Se) and specificity (Sp) of anthropometric indices for cardiovascular risk factors in girls: CASPIAN Study

Age groups	Risk factors	BMI			WC			WHR			WSR		
		Cutoff	Se	Sp	Cutoff	Se	Sp	Cutoff	Se	Sp	Cutoff	Se	Sp
6–9.9 years	High TC	17.3	0.5	0.7	62.5	0.4	0.8	0.8	0.6	0.64	0.47	0.46	0.13
	High LDL-C	17.4	0.4	0.7	59.5	0.5	0.7	0.8	0.5	0.65	0.44	0.57	0.32
	Low HDL-C	15.5	0.5	0.5	55.5	0.6	0.5	0.7	0.8	0.41	0.42	0.77	0.54
	High TG	16.6	0.4	0.7	62.5	0.3	0.8	0.7	0.8	0.25	0.46	0.34	0.15
	High FBS	18.3	0.3	0.8	48.5	1.0	0.0	0.8	0.6	0.72	0.40	1.00	0.79
	High SBP/DBP	16.9	0.5	0.7	63.5	0.3	0.8	0.8	0.3	0.84	0.47	0.34	0.16
10–13.9 years	High TC	16.8	0.8	0.2	75.5	0.2	0.8	0.8	0.4	0.82	0.44	0.60	0.37
	High LDL-C	17.9	0.7	0.4	62.5	0.7	0.3	0.7	0.8	0.41	0.43	0.61	0.41
	Low HDL-C	21.4	0.2	0.7	61.5	0.7	0.3	0.7	0.6	0.47	0.41	0.69	0.55
	High TG	18.5	1.0	0.0	72.5	0.3	0.8	0.8	0.3	0.73	0.43	0.54	0.35
	High FBS	25.3	0.3	0.9	64.5	0.8	0.4	0.7	1.0	0.42	0.41	1.00	0.58
	High SBP/DBP	18.3	0.7	0.4	71.5	0.4	0.7	0.8	0.5	0.65	0.44	0.59	0.37
14–18 years	High TC	21.0	0.6	0.5	72.5	0.4	0.6	0.7	0.4	0.68	0.43	0.73	0.50
	High LDL-C	21.2	0.6	0.6	69.5	0.6	0.5	0.8	0.3	0.77	0.43	0.68	0.51
	Low HDL-C	23.1	0.3	0.7	68.5	0.5	0.5	0.7	0.5	0.59	0.45	0.40	0.29
	High TG	21.4	1.0	0.0	70.5	0.6	0.6	0.7	0.4	0.70	0.43	0.63	0.41
	High FBS	21.2	0.6	0.5	65.5	1.0	0.3	0.7	1.0	0.36	0.45	0.67	0.33
	High SBP/DBP	19.1	0.9	0.3	68.5	0.8	0.5	0.7	0.8	0.43	0.42	0.80	0.55

BMI: body mass index (kg/m^2), WC: waist circumference (cm), WHR: waist-to-hip ratio, WSR: waist-to-stature ratio, high TC: total cholesterol ≥ 95th age and gender-specific percentile, high LDL-C: low-density cholesterol ≥ 95th age and gender-specific percentile, low HDL-C: high-density cholesterol ≤ 5th age and gender-specific percentile, high TG: triglyceride ≥ 95th age and gender-specific percentile, high FBS: fasting blood sugar ≥ 100 mg/dl, high SBP/DBP: systolic/diastolic blood pressure ≥ 90th age and gender-specific percentile.

[a] The optimal cutoff value was denoted by the value that had the largest sum of sensitivity and specificity.

value of BMI for CVD risk factors [44]. However, since this index cannot distinguish fat from muscle mass, and cannot represent the fat distribution, some scientific groups stated that as an overall obesity index, BMI could not be appropriate in predicting CVD [9].

Different studies have documented that similar to adults, WC is an indicator of abdominal fat content, and consequently is a good predictor of CVD risk factors among children and adolescents, as well [45]. However, still there is no global standard for WC in youth. The cutoff values differ between genders, different races and ethnic groups.

In 2004, WHO suggested that in adults, lower cutoff points of BMI should be retained for Asians because the risk factors for CVD at a given BMI are generally higher among Asians compared with Western populations [46]. Since the growth rate and fat patterning vary between different populations [47], it is important to develop simple and effective anthropometric indices for the screening of higher metabolic risk subjects in different populations until reaching internationally-accepted measures.

Certain factors might have influenced the findings of the present study, we wish to acknowledge that the serum lipid levels are compared to the Lipid Research Clinic (LRC) data, which are not necessarily universally healthful standards, but are nevertheless useful for comparative purposes in this study. In addition, the differences for the association of anthropometric indices with CVD risk factors were often small, and with overlapping confidence intervals.

5. Conclusion

In the present study, BMI, WC and WSR were the best indices for predicting CVD risk factors among children and adolescents. It may be clinically useful in the pediatric population to routinely measure WC and WSR in addition to BMI as a screening tool to identify high-risk youth.

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