

## Original Article

# Waist Circumference is Better Than Other Anthropometric Indices for Predicting Cardiovascular Disease Risk Factors in Chinese Children—a Cross-Sectional Study in Guangzhou

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**Aim:** To determine the best anthropometric index among body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), and waist-to-stature ratio (WSR) and to derive optimal thresholds for predicting CVD risk factors in Chinese children.

**Methods:** A total of 2563 children aged 8–12 years were recruited in Guangzhou, China. Anthropometric indices were measured in all participants. Systolic and diastolic blood pressure (SBP and DBP, respectively), glucose, triglyceride (TG), total cholesterol, high-density lipoprotein cholesterol (HDL-C) and low-density lipoprotein cholesterol (LDL-C) were measured in a subsample of 1609 children.

**Results:** In partial correlation analyses, the highest coefficients were found for WC in four risk factors in both genders. The receiver operating characteristic (ROC) analyses showed that WC was comparably consistent among the best in predicting BP and risk factor clustering, WC and WSR were the best in predicting HDL-C and TG in boys; WC, slightly better than BMI, was the best in distinguishing high BP and risk factor clustering in girls. In contrast, WHR was consistently the poorest index in both genders. Optimal age- and gender-specific thresholds to identify individual and clustering risk factors were provided; the thresholds for WC were 57.4–80.4 cm and 55.8–69.6 cm in boys and girls, respectively.

**Conclusions:** WC was the comparatively consistent and best predictor of CVD risk factors compared with WSR and BMI, although the differences were small and depended on the type of risk factor and gender, and WHR was consistently the poorest predictor in Chinese children.

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**Key words:** Anthropometry, Body composition, Blood pressure, Lipid, Glucose

## Introduction

Studies have showed that adiposity is associated with adverse levels of cardiovascular disease (CVD) risk factors in children<sup>1</sup>. The growing prevalence of

childhood obesity highlights the need to screen high CVD risk children for targeted interventions<sup>2</sup>. Various anthropometric indices of obesity have been suggested to predict CVD risks based on weight, height, waist circumference (WC), and hip circumference; however, the results produced substantially different proportions of subjects at an increased CVD risk<sup>3</sup>.

Body mass index (BMI), which is an index of general obesity, has been widely used across disciplines ranging from international surveillance to individual patient assessment<sup>4</sup>. However, after Vague's first obser-

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vation that android obesity among women was associated with diabetes and atherosclerosis<sup>5)</sup>, the importance of fat distribution in relation to various diseases was increasingly recognized<sup>6)</sup>. From the 1980s, studies have showed that obesity related adverse health consequences occur predominately in individuals with upper body fat accumulation, commonly associated with visceral obesity<sup>7)</sup>. WC and WC-derived indices such as waist-to-hip ratio (WHR) and waist-to-stature ratio (WSR) have been used as proxy measures of fat distribution. Although WSR has been found to be a better indicator than other anthropometric indices of CVD risk factors in adults<sup>8)</sup>, the choices in children remain a matter of an ongoing debate. A recent research showed that BMI reference charts are useful to predict CVD risk factors in North American and Australian children, but this was questioned in European and Asian children<sup>9)</sup>. The results of studies were complicated even in Asian children. The CASPIAN study conducted in Iran showed that BMI, WC, and WSR have equal abilities for predicting CVD risk factors among children<sup>10)</sup>. However, the study of Hara *et al.* showed that WSR is the best predictor in Japanese school children<sup>11)</sup>.

There was limited data showing the associations of BMI and WC with CVD risk factors in Hong Kong and Xinjiang province<sup>12, 13)</sup>, and no data were available to comprehensively evaluate the screening ability of WC, BMI, WHR, and WSR among Chinese children in the south of mainland, which has a different climate and dietary habits compared with the north of China<sup>14)</sup>.

## Aim

The purpose of the present study was to fully determine the best anthropometric index among BMI, WC, WHR, and WSR in relation to CVD risk factors and to develop optimal thresholds of anthropometric indices for predicting high levels of these factors in Chinese children.

## Methods

### Subjects

This study was conducted as part of the baseline survey of a multi-center interventional project titled "A national school-based health lifestyles interventions among Chinese children and adolescents against obesity: rationale, design and methodology of a randomized controlled trial in China"<sup>15)</sup>. The present paper described a sub-sample of primary school students which was obtained in Guangzhou, Guangdong prov-

ince. Through a multistage cluster sampling, we first randomly selected five primary schools from the 10 urban districts from September to October 2013, and in a second stage, all of the students in grade 2–5 and aged 8–12 years in these schools were invited to participate in this survey ( $n=2563$ ; boys: 1283, girls: 1280). The detailed sampling method was described in the previous study<sup>15)</sup>. All of the included students took weight, height, WC, hip circumference, and blood pressure (BP) measurements, and 62.8% of them agreed to participate in blood sample collection and measurement of biochemical variables, including fasting glucose (GL), total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), and triglyceride (TG) ( $n=1609$ ; boys: 810, girls: 799). No significant difference was found between the blood sample participants and the rest of the participants among age, gender, height, weight, BMI, BP, WC, WSR, and WHR. Responders may be considered to be representative of the population studied. The height, weight, WC, and hip circumference data from the whole population ( $n=2563$ ) were used to construct reference WC, BMI, WSR, and WHR percentile charts for this population.

Written informed consent was obtained from both students and their parents. The study protocol was approved by the Ethical Committee of Sun Yat-sen University.

### Body Composition

Height, weight, and waist and hip circumference were measured according to standardized methods by trained doctors, with the child wearing light clothing. WC was measured at 1 cm above the umbilicus with a non-elastic tape. Hip circumference was measured at the maximal protrusion of the buttocks. Weight was measured to the nearest 0.1 kg, and height and hip and waist circumference were measured to the nearest 0.1 cm. The average of three consecutive measures was used in the analyses. BMI is calculated by dividing weight in kilograms by height in meters squared ( $\text{kg}/\text{m}^2$ ). Overweight and obesity were defined using the Working Group of Obesity in China (WGOC) criteria<sup>16)</sup>. Next, WHR and WSR were computed by dividing WC by the hip and stature, respectively.

### CVD Risk Factors

BP was measured from the right arm using a validated mercury sphygmomanometer (model XJ1ID, China) and TZ-1 stethophone. The mid upper arm circumference determined cuff size. The cuff was placed approximately 2 cm above the crease of the

elbow. The child was seated comfortably for at least 5 min prior to the first reading. The first Korotkoff phase was used to determine systolic blood pressure (SBP), and the fifth Korotkoff phase was used to determine diastolic blood pressure (DBP). BP was measured two times, with one minute between each measurement. Children were asked to remain quiet and to sit still while each reading was being taken. The average of the two BP measurements were recorded and included in the analyses. The same researcher took all BP measurements.

After a 12-h overnight fast, venous blood samples (5 ml) were taken from the antecubital vein and collected into ethylenediaminetetraacetic acid (EDTA) vacuum tubes before breakfast. Samples were centrifuged at 3000r, and they were aliquoted and stored at  $-80^{\circ}\text{C}$ . Biochemical indicators, including GL, TG, TC, HDL-C, and LDL-C, were tested at a biomedical analyses company, which is accredited by Peking University. GL was measured by glucose oxidase method; TG and TC were measured by enzymatic methods; and HDL-C and LDL-C were measured by clearance method<sup>15</sup>.

### Definition of Risk Factors

WC, BMI, WHR, and WSR of all the children, categorized according to gender, were regressed with respect to age (with up to a cubic polynomial of terms: age, age<sup>2</sup>, and age<sup>3</sup>) using stepwise liner regression procedures to provide age- and gender-specific regression equations. Each CVD risk factor value was similarly regressed with respect to age in these participants to provide age- and gender-specific regression equations. The standardized residuals of all anthropometric indices and CVD risk factors for all children were retained to represent age- and gender-adjusted Z score values. Because no standardized cutoffs currently exist for this age group<sup>17, 18</sup>, a participant having any of the following was considered to have a CVD risk factor: 1) age- and gender-adjusted TG/TC/LDL-C/GL  $\geq 90$ th percentile; 2) age- and gender-adjusted HDL-C  $\leq 10$ th percentile; and 3) the age- and gender-adjusted mean SBP or DBP above the 90th percentile<sup>18</sup>. Participants were considered to have clustering of risk factors if three or more of the seven risk factors were present.

### Statistical Analysis

Descriptive results were expressed as mean and standard deviation. Anthropometric values and CVD parameters were compared among gender groups using Student's *t*-test for continuous variables with a normal distribution and the nonparametric test for those without a normal distribution. To determine

which was the best anthropometric index, two statistical methods was used. First, partial correlations were performed between CVD risk factors and anthropometric indices after adjusting for age as a continuous variable. Second, receiver operating characteristic (ROC) analysis was employed to investigate the diagnostic ability of age- and gender-adjusted WC, BMI, WHR, and WSR to identify the presence or absence of risk factor clustering in the participants. The area under the ROC curve (AUC) was used to give a measurement of the global performance of using these anthropometric indices as effective diagnostic indicators. The value (age-adjusted WC, BMI, WHR, and WSR) 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 CVD risk factors in that it maximizes both sensitivity and specificity. The maximum value of the sum of sensitivity and specificity corresponded to the optimal cutoff Z score of each index for each outcome. For the purpose of comparing the AUCs, MedCalc 13.0 was employed. Smoothed age- and gender-specific percentiles were constructed using the LMS ChartMaker Light software package (The Institute of Child Health, London) for the whole population group. Age- and gender-specific indices thresholds were read from the corresponding percentiles generated using the LMS method from the whole population group ( $n=2563$ ).

Statistical analyses were performed with the Statistical Package for the Social Sciences (SPSS) 17.0, MedCalc 13.0, and LMS ChartMaker Light. All statistical tests were two-sided, and a *P*-value  $< 0.05$  was considered statistically significant.

## Results

The anthropometric indices and CVD risk factors of all the participants are shown in **Table 1**. All of the anthropometrics indices of boys were significantly higher than those of girls. The prevalence of overweight and obesity of boys are significantly higher than that of girls. The prevalence of each high risk factor was not significantly different in terms of gender. However, boys had higher mean values of BP and GL, while girls had higher levels of TG. The correlations between each of the four anthropometric indices were very strong, with the greatest *r* of 0.93 and 0.90 in boys and girls, respectively (WC and BMI). The correlation coefficients of WHR with other indices were comparatively smaller, particularly with BMI, in both genders (**Table 2**).

As illustrated in **Table 3**, WC had the highest coefficients with CVD risk factors in both total popu-

**Table 1.** Demographic and cardiovascular risk factor characteristics of 2563 participants in Guangzhou Chinese children aged 8–12 years

Characteristics	Boys ( <i>n</i> = 1283)		Girls ( <i>n</i> = 1280)		Total ( <i>n</i> = 2563)	
	Mean	SD	Mean	SD	Mean	SD
Age (years)	9.2 <sup>*</sup>	1.1	9.1	1.0	9.2	1.1
Height (cm)	136.2 <sup>*</sup>	8.4	135.5	9.4	135.8	9.0
Weight (kg)	32.4 <sup>*</sup>	9.0	29.2	7.4	30.8	8.4
WC (cm)	61.1 <sup>*</sup>	9.6	58.2	7.6	59.6	8.8
BMI (kg/m <sup>2</sup> )	17.3 <sup>*</sup>	3.4	15.7	2.4	16.5	3.0
Overweight <i>n</i> (%)	162 (12.6%) <sup>*</sup>	–	75 (5.8%)	–	237 (9.2%)	–
Obesity <i>n</i> (%)	161 (12.5%) <sup>*</sup>	–	45 (3.5%)	–	206 (8.0%)	–
WHR	0.89 <sup>*</sup>	0.05	0.86	0.05	0.87	0.05
WSR	0.45 <sup>*</sup>	0.06	0.43	0.04	0.44	0.05
SBP (mmHg)	98.1 <sup>*</sup>	9.2	94.7	8.6	96.4	9.1
DBP (mmHg)	62.1 <sup>*</sup>	7.1	60.4	7.0	61.3	7.1
TC (mmol/L) <sup>#</sup>	4.5	0.8	4.6	0.8	4.5	0.8
HDL-C (mmol/L) <sup>#</sup>	1.5	0.4	1.4	0.3	1.4	0.3
LDL-C (mmol/L) <sup>#</sup>	2.6	0.7	2.6	0.7	2.6	0.7
GL (mmol/L) <sup>#</sup>	4.7 <sup>*</sup>	0.5	4.5	0.4	4.6	0.4
TG (mmol/L) <sup>#</sup>	0.8 <sup>*</sup>	0.5	0.9	0.4	0.8	0.4
CVD risk factors <i>n</i> (%)						
High BP (High SBP or DBP)	81 (10%)	–	79 (9.9%)	–	160 (9.9%)	–
High TC	79 (9.8%)	–	79 (9.9%)	–	158 (9.8%)	–
High HDL-C	85 (10.5%)	–	87 (10.9%)	–	172 (10.7%)	–
High LDL-C	80 (9.9%)	–	79 (9.9%)	–	159 (9.9%)	–
High GL	81 (10%)	–	78 (9.8%)	–	159 (9.9%)	–
High TG	81 (10%)	–	79 (9.9%)	–	160 (9.9%)	–

WC: waist circumference (cm), BMI: body mass index (kg/m<sup>2</sup>), WHR: waist-to-hip ratio, WSR: waist-to-stature ratio, SBP: systolic blood pressure (mmHg), DBP: diastolic blood pressure (mmHg), HDL: high-density lipoprotein cholesterol (mmol/L), LDL: low-density lipoprotein cholesterol (mmol/L), TC: total cholesterol, GL: glucose, TG: triglyceride, SD: standard deviation

<sup>\*</sup>*P* < 0.05, compared with girls;

<sup>#</sup>The sample size of TC, TG, HDL-C, LDL-C, and TC was 1609 (boys: 810, girls: 799).

lation and different gender groups after adjusting for age. All of the CVD risk factors correlated significantly with anthropometric indices, except GL. Further analyses in gender groups showed that GL in boys and GL, TC, and LDL-C in girls were not significantly correlated with anthropometric indices.

As shown in **Table 4** and **Table 5**, both clustering and individual risk factors were analyzed in this study. The comparison of AUCs showed that WC and WSR were the best among the four indices to predict clustering of risk factors; WC was the best for SBP and DBP, WC and WSR have the similar largest AUCs for HDL-C and TG, and no significant differences were found in AUCs of all anthropometric indices for LDL-C in boys. In girls, WC had the highest AUCs for the clustering of risk factors, WC and BMI had the similar largest AUCs for SBP and DBP, and no significant differences were found in AUCs of all

indices for HDL-C and TG.

**Tables 6** showed the smoothed, sex- and age-specific cutoff values for four anthropometric indices using the LMS method. Overall, the cutoff values increased with age in both genders (except WHR and WSR in girls), and boys had higher values than girls at each age.

## Discussion

The associations of four adiposity-related anthropometric indices with individual and clustering of CVD risk factors were analyzed in Chinese children aged 8–12 years living in Guangzhou. In the partial correlation analysis, the highest coefficient was found for WC in 4 of 7 CVD risk factors in both genders. The ROC analyses showed that WC was comparably consistent among the best in predicting BP together

**Table 2.** Age- and gender-adjusted partial correlation coefficients regarding the association between anthropometric indices in Guangzhou Chinese children aged 8–12 years ( $n = 1609$ )

	BMI		WC		WHR		WSR	
	$\gamma$	P	$\gamma$	P	$\gamma$	P	$\gamma$	P
Boys								
BMI	1.00	–	0.93	<0.01	0.49	<0.01	0.91	<0.01
WC	0.93	<0.01	1.00	–	0.62	<0.01	0.93	<0.01
WHR	0.49	<0.01	0.62	<0.01	1.00	–	0.72	<0.01
Girls								
BMI	1.00	–	0.90	<0.01	0.44	<0.01	0.85	<0.01
WC	0.90	<0.01	1.00	–	0.54	<0.01	0.87	<0.01
WHR	0.44	<0.01	0.54	<0.01	1.00	–	0.72	<0.01
Total								
BMI	1.00	–	0.92	<0.01	0.49	<0.01	0.90	<0.01
WC	0.92	<0.01	1.00	–	0.64	<0.01	0.94	<0.01
WHR	0.49	<0.01	0.64	<0.01	1.00	–	0.72	<0.01

BMI: body mass index, WC: waist circumference, WHR: waist-to-hip ratio, WSR: waist-to-stature ratio

**Table 3.** Age- and gender-adjusted partial correlation coefficients between cardiovascular risk factors and anthropometric indices in Guangzhou Chinese children aged 8–12 years

	Boys ( $n = 810$ )				Girls ( $n = 799$ )				Total ( $n = 1609$ )			
	BMI	WC	WHR	WSR	BMI	WC	WHR	WSR	BMI	WC	WHR	WSR
SBP	0.46*	0.47*	0.24*	0.42*	0.25*	0.27*	0.05	0.17*	0.37*	0.38*	0.15*	0.31*
DBP	0.35*	0.38*	0.23*	0.34*	0.21*	0.23*	0.08*	0.14*	0.29*	0.31*	0.16*	0.25*
TC	0.12*	0.11*	0.02	0.12*	–0.02	–0.04	–0.01	–0.03	0.06*	0.05	0.01	0.05*
HDL	–0.25*	–0.32*	–0.26*	–0.31*	–0.22*	–0.23*	–0.17*	–0.23*	–0.26*	–0.28*	–0.22*	–0.27*
LDL	0.23*	0.23*	0.11*	0.23*	0.07	0.06	0.04	0.04	0.16*	0.15*	0.07*	0.15*
TG	0.38*	0.41*	0.31*	0.40*	0.27*	0.28*	0.22*	0.27*	0.34*	0.36*	0.27*	0.35*
GL	0.03	0.01	0.01	0.01	0.04	0.06	0.05	0.05	0.03	0.03	0.02	0.03

SBP: systolic blood pressure, DBP: diastolic blood pressure, HDL-C: high-density lipoprotein cholesterol, LDL-C: low-density lipoprotein cholesterol, TG: triglyceride, TC: total cholesterol, GL: glucose, BMI: body mass index, WC: waist circumference, WHR: waist-to-hip ratio, WSR: waist-to-stature ratio

\* $P < 0.05$ .

with risk factor clustering; WC and WSR were the best in predicting HDL-C and TG in boys; and WC, slightly better than BMI, was the best in distinguishing high SBP, DBP, and risk factor clustering in girls. In contrast, WHR was consistently the poorest index in the two methods of analyses in both genders. Further, it was found that the associations between anthropometric indices and CVD risk factors were stronger in boys than in girls, and no significant associations were found for indices with TC and GL.

WC consistently showed better associations than BMI with CVD risk factors, with significant differences in boys in this study. It is consistent with the research in Hong Kong Chinese children, which pro-

posed that WC correlated slightly more than BMI with CVD risk factors<sup>17</sup>). Although BMI is routinely used to evaluate weight status and general obesity, there is increasing evidence that the indices of abdominal obesity, such as WC and WSR, are better predictors for cardiovascular complications<sup>19</sup>). Further comparison indicated that WC had slightly better predictive abilities than WSR with BP, but similar for HDL-C, TG, and clustering risk factors in boys, while WC was consistently better than WSR for all risk factors in girls. Other studies in western countries also showed that WC was a better predicting index in children<sup>20, 21</sup>). The Bogalusa Heart Study showed that WC was a strong predictor of visceral fat, which is a strong risk

**Table 4.** Area under the receiver operating curve, optimal cutoff value, and sensitivity and specificity for anthropometric indices as predictors of cardiovascular risks factors in Guangzhou Chinese boys aged 8–12 years ( $n=810$ )

Indices	SBP*	DBP*	TC	HDL-C*	LDL-C*	TG*	GL	≥ 3 risk factors clustering*
<b>BMI</b>								
AUC	0.76 <sup>b</sup>	0.72	0.55	0.67	0.63	0.77	0.50	0.78
Thresholds <sup>d</sup>	0.66	0.11	0.06	−0.09	0.06	0.42	−0.60	0.38
Percentiles	77	64	62	59	62	72	59	70
Sensitivity	0.63	0.74	0.52	0.71	0.60	0.74	0.72	0.77
Specificity	0.81	0.68	0.64	0.60	0.65	0.76	0.33	0.73
<b>WC</b>								
AUC	0.77 <sup>b, c</sup>	0.76 <sup>a, b, c</sup>	0.55	0.70 <sup>a</sup>	0.64	0.79 <sup>a</sup>	0.49	0.83 <sup>a, b</sup>
Thresholds <sup>d</sup>	0.26	0.07	0.20	−0.09	1.16	0.20	−0.18	0.12
Percentiles	68	64	67	59	85	67	55	65
Sensitivity	0.74	0.78	0.51	0.72	0.36	0.78	0.49	0.88
Specificity	0.73	0.68	0.68	0.62	0.87	0.71	0.55	0.67
<b>WHR</b>								
AUC	0.68	0.70	0.54	0.72	0.60	0.76	0.49	0.78
Thresholds <sup>d</sup>	0.92	0.91	0.89	0.92	0.91	0.89	0.89	0.92
Percentiles	78	72	58	78	72	58	58	78
Sensitivity	0.52	0.53	0.56	0.55	0.51	0.83	0.51	0.71
Specificity	0.78	0.73	0.56	0.81	0.72	0.61	0.54	0.77
<b>WSR</b>								
AUC	0.75 <sup>b</sup>	0.74	0.56	0.69 <sup>a</sup>	0.63	0.79 <sup>a</sup>	0.50	0.83 <sup>a, b</sup>
Thresholds <sup>d</sup>	0.47	0.47	0.46	0.46	0.49	0.46	0.44	0.47
Percentiles	70	70	66	66	76	66	60	70
Sensitivity	0.70	0.69	0.49	0.64	0.50	0.79	0.51	0.85
Specificity	0.75	0.73	0.66	0.68	0.77	0.71	0.59	0.73

WC: waist circumference, BMI: body mass index, WHR: waist-to-hip ratio, WSR: waist-to-stature ratio, SBP: systolic blood pressure, DBP: diastolic blood pressure, HDL-C: high-density lipoprotein cholesterol, LDL-C: low-density lipoprotein cholesterol, TG: triglyceride, TC: total cholesterol, GL: glucose

<sup>a</sup>Compared with BMI,  $P < 0.05$ ; <sup>b</sup>compared with WHR,  $P < 0.05$ ; <sup>c</sup>compared with WSR,  $P < 0.05$ ; <sup>d</sup>Thresholds referred to age- and gender-adjusted standard residual threshold values;

\*High risk significantly predicted by all indices.

factor of CVD in children<sup>22</sup>). However, a research conducted in Brazil involving children aged 6–18 years showed that WSR was the best anthropometric predictor for CVD risk factors. Despite the heterogeneity between studies making the comparison difficult, such as the different definitions of outcomes and the ethnicity of participants, some explanations could be provided. The rationale for the use of WSR is that, for a given height, there is acceptable range of fat stored in the upper portion of the body. Studies indicated that WSR may be a more appropriate measurement of adiposity distribution than single WC measurement in populations with a wide range of heights<sup>23</sup>). TYBOR *et al.* also found that the residual correlation of WSR with height affected relationships between central adiposity and CVD risk factors at a certain age of childhood; thus, simply dividing WC by height

might not be appropriate to “adjust for height” during periods of growth<sup>24</sup>). It is difficult to interpret the correlation between WSR and risk factors biologically, which is complicated by the possible relation of disease risk to height<sup>25</sup>). Further, studies of the best predicting index in children are complicated by the rapid changes in fat patterning that occur during growth and development, particularly at pubertal age; thus, the best distinguishing index of children may be different from that of adults<sup>26</sup>).

In adults, a large number of studies showed that WSR was slightly better than WC and BMI for detecting CVD risk factors in both males and females<sup>27</sup>). For instance, two recent studies in Beijing and Hong Kong both showed that WSR performed better than BMI and WC for the association with CVD risk factors<sup>28, 29</sup>). One of the most important advantages of

**Table 5.** Area under the receiver operating curve, optimal cutoff value, and sensitivity and specificity for anthropometric indices as predictors of cardiovascular risks factors in Guangzhou Chinese girls aged 8–12 years ( $n=799$ )

Indices	SBP*	DBP*	TC	HDL-C*	LDL-C	TG*	GL	≥ 3 risk factors clustering*
<b>BMI</b>								
AUC	0.69 <sup>b, c</sup>	0.68 <sup>b</sup>	0.47	0.64	0.54	0.66	0.51	0.72
Thresholds <sup>d</sup>	−0.15	−0.01	0.85	0.56	0.85	0.51	0.34	0.51
Percentiles	55	60	83	78	83	77	71	77
Sensitivity	0.71	0.67	0.24	0.45	0.29	0.51	0.36	0.56
Specificity	0.64	0.63	0.84	0.81	0.84	0.80	0.72	0.79
<b>WC</b>								
AUC	0.70 <sup>b, c</sup>	0.69 <sup>b, c</sup>	0.48	0.65	0.54	0.69	0.53	0.73 <sup>b, c</sup>
Thresholds <sup>d</sup>	0.18	0.18	0.66	0.37	0.26	0.05	−0.54	0.05
Percentiles	67	67	80	72	70	62	50	62
Sensitivity	0.61	0.61	0.28	0.49	0.43	0.65	0.76	0.73
Specificity	0.70	0.69	0.80	0.74	0.71	0.65	0.31	0.64
<b>WHR</b>								
AUC	0.57	0.58	0.53	0.62	0.56	0.63	0.48	0.64
Thresholds <sup>d</sup>	0.89	0.88	0.90	0.88	0.90	0.87	0.93	0.90
Percentiles	78	71	82	71	82	64	94	82
Sensitivity	0.39	0.45	0.23	0.48	0.28	0.65	0.09	0.40
Specificity	0.73	0.73	0.85	0.71	0.86	0.58	0.94	0.86
<b>WSR</b>								
AUC	0.65 <sup>b</sup>	0.65 <sup>b</sup>	0.48	0.64	0.55	0.68	0.49	0.70 <sup>b</sup>
Thresholds <sup>d</sup>	−0.01	0.35	1.16	−0.16	0.41	−0.09	−0.83	0.35
Percentiles	58	71	87	58	73	60	40	71
Sensitivity	0.66	0.51	0.19	0.69	0.38	0.73	0.89	0.62
Specificity	0.61	0.74	0.88	0.55	0.74	0.58	0.18	0.73

WC: waist circumference, BMI: body mass index, WHR: waist-to-hip ratio, WSR: waist-to-stature ratio, SBP: systolic blood pressure, DBP: diastolic blood pressure, HDL-C: high-density lipoprotein cholesterol, LDL-C: low-density lipoprotein cholesterol, TG: TRIGLYCERIDE, TC: total cholesterol, GL: glucose

<sup>a</sup>Compared with BMI,  $P < 0.05$ ; <sup>b</sup>compared with WHR,  $P < 0.05$ ; <sup>c</sup>compared with WSR,  $P < 0.05$ ; <sup>d</sup>Thresholds referred to age- and gender-adjusted standard residual threshold values;

\*High risk significantly predicted by all indices.

WSR compared with BMI, even with WC and WHR, is that a simple message that one's WC should not exceed half the stature could be recommended for the adult population. However, a recent review showed that the cutoff value, 0.5 of WSR, was not appropriate for young children because of its low specificity, and the author further suggested the WSR cutoff should be different for children and adolescents aged 6–12 and 12–18 years old, respectively<sup>30</sup>. In our research, regression analyses showed that WSR was significantly associated with age and gender ( $\beta$ , 0.02 for age and  $-0.018$  for gender); thus, WSR is not an age- and gender-independent index in children. The research conducted in Hong Kong Chinese children also showed that WSR was not independent of age under 14 years<sup>31</sup>. Therefore, the use of WSR does not obviate the need for age- and gender-related reference

standards. Although the reproducibility of WC measurements may be lower than that for BMI, a recent systematic review showed that the WC measurement protocol has no substantial influence on the association between WC and CVD risk factors<sup>32</sup>. Therefore, WC may be optimal to identify children who are likely to have an adverse level of CVD risk factors.

WHR may not be of clinical importance in predicting high CVD risk factor levels in Chinese children because none of the CVD risk factors showed associations with WHR that were superior to the other anthropometric indices.

In view of the inconsistent definitions of the Metabolic Syndrome and increasing the comparability with other studies, the data were analyzed using both individual and clustering CVD risk factors. The differences are small but suggest slightly larger sensitivity

**Table 6.** Optimal anthropometric indices cutoff values derived from the percentile values in the ROC analyses using the LMS method in Guangzhou Chinese children aged 8–12 years ( $n = 2563$ )

Cutoff	$\geq 1$ risk factor <sup>a</sup>				$\geq 3$ risk factor <sup>d</sup>			
	BMI (kg/m <sup>2</sup> )	WC (cm)	WHR	WSR	BMI (kg/m <sup>2</sup> )	WC (cm)	WHR	WSR
Boys <sup>b</sup>								
8	16.5–17.9	57.4–64.1	0.89–0.92	0.45–0.47	17.2	58.6	0.92	0.46
9	17.1–18.8	60.5–68.5	0.89–0.92	0.45–0.47	18.0	61.8	0.92	0.46
10	17.8–19.7	63.3–72.8	0.89–0.92	0.46–0.48	18.8	64.8	0.92	0.47
11	18.2–20.4	65.5–76.3	0.89–0.92	0.46–0.49	19.4	67.2	0.92	0.47
12	18.8–21.3	68.0–80.4	0.89–0.92	0.48–0.50	20.1	69.9	0.92	0.49
Girls <sup>c</sup>								
8	15.0–16.3	55.8–57.5	0.87–0.89	0.43–0.45	16.2	55.8	0.89	0.45
9	15.5–17.1	58.8–60.7	0.87–0.88	0.43–0.45	17.0	58.8	0.88	0.45
10	15.9–17.6	61.3–63.5	0.86–0.88	0.43–0.44	17.5	61.3	0.88	0.44
11	16.5–18.4	64.1–66.6	0.85–0.87	0.43–0.45	18.3	64.1	0.87	0.45
12	17.2–19.3	66.9–69.6	0.84–0.86	0.43–0.44	19.2	66.9	0.86	0.44

BMI: body mass index, WC: waist circumference, WHR: waist-to-hip ratio, WSR: waist-to-stature ratio

<sup>a</sup>Threshold ranges of anthropometric indices in relation to the significantly predicted seven CVD risk factors were provided;

<sup>b</sup>SBP, DBP, HDL-C, LDL-C, and TG were significantly predicted;

<sup>c</sup>SBP, DBP, HDL-C, and TG were significantly predicted;

<sup>d</sup> $\geq 3$  risk factors of the seven CVD risk factors.

and specificity than individual CVD risk factors. Further, the most strong associations for individual CVD risk factors of the seven were SBP, DBP, TG, and HDL-C, but LDL-C and TC, particularly GL, were only weakly or insignificantly associated with anthropometric indices, a hierarchy of individual associations similar to that noted in Chinese children previously<sup>17, 33</sup>. A recent systematic review showed that correlations with anthropometric indices tended to be significant and stronger for SBP than DBP, for TG and HDL-C than other lipid outcomes, and for insulin resistance than GL being assessed in the same studies of children<sup>34</sup>. Insulin resistance is thought to play a critical role in the pathogenesis of type 2 diabetes (T2D) among children<sup>35</sup>. Because of the low prevalence of T2D<sup>36</sup>, it may be more sensitive to screen insulin resistance than GL in children. However, the exact reasons for the differential correlations between each CVD risk factor and obesity indices are unclear. More prospective researches are needed to explore the correlations before definitive conclusions can be made.

Age- and gender-specific references of anthropometric indices to identify both individual and clustering risk factors were established for Chinese children in Guangzhou in this research. Two studies have developed anthropometric indices (only including WC) cutoff values for the clustering of CVD risk factors in Chinese children in the mainland of China. Consistent with findings in this study, WC thresholds

increase with age, and boys have higher cutoff values than girls at each age. However, the specific cutoff values of WC proposed by Liu *et al.*<sup>37</sup> for both boys and girls are higher than those recommended by Yan *et al.*<sup>38</sup>, which are both higher than those of children in our study. A number of factors may explain these differences. Firstly, the complex interaction of genetic and many geographic climate factors in China's long history may affect children's WC and its sensitivity to CVD risk factors<sup>39, 40</sup>. Liu *et al.* involved children mainly from northern China, but children from the northwest are included in the study of Yan *et al.* The WC average levels of participants in the three studies are different (Boys: 64.1 cm in Liu *et al.*, 61.0 cm in Yan *et al.*, and 61.1 cm in our research; Girls: 60.2 cm in Liu *et al.*, 58.0 cm in Yan *et al.*, and 58.2 cm in our research), which showed the same trend as WC cutoff values. In addition, different WC measurement sites, definition standards of the abnormal CVD factors levels and clustering of risk factors, and analysis methods may be accounted for the inconsistency. With the high sensitivity and specificity, the thresholds provided in our study may help in the identification of children who live in southern China with smaller body sizes<sup>41</sup>. However, because there is still no global standard for WC in children and the cutoff values differ between age and gender groups in our research, particularly in girls, more studies are needed to evaluate whether WC is the best and simple anthropometric index for clini-



cal use in children.

One limitation for this study is that the pubertal state is not measured because of the practical difficulty, but only including pre-pubertal children aged 8–12 years may obviate the influence of pubertal state. In addition, the causality between the anthropometric indices and the CVD risk factors cannot be established because of the cross-sectional study design.

## Conclusion

In this cross-sectional study of a representative southern mainland Chinese children sample, WC were slightly superior than WSR and BMI for the screening of both individual and clustering of CVD risk factors, whereas WHR was the poorest predictive index in both genders, although the differences were small and depended on the type of CVD risk factor and gender. Age- and gender-specific thresholds of anthropometric indices to identify individual and clustering CVD risk factors increased with age, except for WSR and WHR in girls, and boys had higher cut-off values than girls at each age.

## Conflicts of Interest Statement

The authors do not have any conflict of interest in connection with the current paper.

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Author contributions: LM collected data, analyzed data, and wrote the manuscript. LC critically reviewed and revised the manuscript. LD collected data and revised the manuscript. JM and JJ designed the study and secured funding. YJC designed the study, critically reviewed and revised the manuscript, and also secured funding.

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