Waist Circumference Reference Values for Screening Cardiovascular Risk Factors in Chinese Children and Adolescents

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Objectives To explore the optimal threshold values of waist circumference (WC) for detecting cardiovascular (CV) risk factors among Chinese children and adolescents. **Methods** Association of WC with CV risk factors was studied among 65 898 children aged 7-18 years whose data were pooled from nine previous studies in China. CV risk factors in this study included hypertension (blood pressure above 95 percentile levels), dyslipidemia (with one or more of the following three indexes: TG≥1.7 mmol/L, TC≥5.18 mmol/L, and HDL-C≤1.04 mmol/L) and elevated glucose level (fasting plasma glucose ≥5.6 mmol/L). Receive-operating characteristic analysis (ROC) and logistic regression were employed to derive optimal age- and sex-specific waist circumference references for predicting CV risk factors. **Results** A slight increasing trend of CV risk factors was observed starting from the 75th percentile of waist circumference in the study population, while a remarkable increasing trend occurred from the 90th percentile. The optimal waist circumference thresholds for predicting high blood pressures were at the 75th percentile for both boys and girls, which was at the 90th percentiles for detecting at least two of the above three CV risk factors. In comparison with children with waist circumference below the 75th percentile, the odds ratio of two CV risk factors doubled among children with waist circumference between the 75th and the 90th percentile, and increased by 6 times among children with waist circumference above the 90th percentile. The trend of high blood pressure increasing with waist circumference remained significant after having been stratified by BMI category. **Conclusion** The 75th and the 90th percentiles of WC are the optimal cut-off points for predicting an increased and a substantially increased risk of CV factors in Chinese children and adolescents, respectively.

Key words: Waist circumference; Cardiovascular disease risk factor; China

INTRODUCTION

The prevalence of childhood obesity is on the rise[1], especially in developing countries where traditional lifestyles have been abandoned, and China is faced with the greatest threat[2]. A total of 155 million children worldwide are overweight or obese[1], of which 12 million live in China[3]. The overweight children, when compared to their counterparts with normal weight, are much more likely to be affected with a number of cardiovascular risk factors, including atherogenic dyslipidemia (increased triglycerides, lowered high-density lipoprotein), hypertension, abnormal fasting glucose and insulin levels, early atherosclerosis and obstructive sleep apnea[4-8]. Overweight and associated precursors of cardiovascular disease risk factors may persist into adulthood[9-11]. Effective interventions are needed to prevent the early onset of clinical cardiovascular diseases among children[12], and the earlier the better.

The predisposition of abdominal obesity is thought to be one of the causes of high risk to diabetes and cardiovascular diseases associated with obesity in Asians[2], considering the fact that Asians have lower body mass index (BMI) but higher percentage of body fat than their white

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counterparts[13]. Waist circumference is an indicator of abdominal fat content[14], and consequently is a good independent indicator of insulin resistance, dyslipidemia and hypertension in children[15] and adults[16]. Therefore, waist circumference is included in the pediatric metabolic syndrome criteria for the screening of children with high risk of metabolic syndrome[17-18]. However, since the growth rate and fat accumulation pattern vary among different populations[19-21], it is important to develop the waist circumference percentile curves and establish the optimal waist circumference threshold in them.

Four studies on waist circumference and its related cardiovascular risk factors in Chinese children have been published based on the data of Hong Kong[22], Beijing[23], Xinjiang[24], and Chongqing[25], respectively. However, data on nationally representative samples are lacking.

Ji *et al.*[26] have recently developed waist circumference percentile curves based on the China nationally representative data of 160 225 students aged 7-18 years using the LMS method. However, the information on disease risk factors is lacking. In order to develop the optimal waist circumference cut-off points for predicting cardiovascular disease risk, data from nine studies on waist circumference risk factors in China were pooled.

MATERIALS AND METHODS

Sampling Method

The current analyses were based on the data from 9 studies including "Waist circumference and weight-to-height ratio of Hong Kong Chinese children"[22]; "Use of waist circumference and waist-to-height ratio to access central obesity in children and adolescents in Beijing"[23]; "Study on the relationship of waist circumference, waist-to-height ratio, waist-hip ratio and blood pressure in children and adolescents"[24] (Chongqing); "Waist circumference cut-off points in school-aged Chinese Han and Uygur children" (Xinjiang)[25]; "Fasting glucose and serum lipids level of normal-weight, overweight and obese children in Beijing" (Beijing)[27]; "The relationship between the BMI, WHR and serum lipid levels in adolescents" (Beijing)[28]; "The 2002 China National Nutrition and Health Survey" (31 provinces)[29]; Baseline data of "Effect of school based physical activity intervention study" (Beijing)[30-31]; and "Waist circumference cut-off values for the prediction of cardiovascular risk in Chinese school-aged children" (Liaoyang, Tianjin, and Guangzhou).

The above 9 studies were performed from 2002 to 2008, meeting the following inclusion criteria: (1) Subjects were between 7 and 18 years old; (2) The sample size was required to be≥900; (3) Variables at least included, but were not limited to age, sex, height, weight, and waist circumference; (4) At least one of the following CV risk factors were included: blood pressure, glucose, HDL, LDL, TG, and TC; and (5) Internal and external quality assessment of their clinical measurements.

Data analysis was based on the original data pooled from the selected 9 studies. From the pooled studies, data were available from a total of 65 898 subjects with blood pressure, 11 683 with lipid profiles, 12 544 with glucose concentration, and 11 193 with all these variables. Sample size of the original studies and measurements of the CV risk factors are listed in Table 1.

Definitions of CV Risk Factors

CV risk factors in the present study included high blood pressure, elevated glucose level and dyslipidemia. High blood pressure was defined as systolic blood pressure and/or diastolic blood pressure >95th age and gender specific percentile developed by Xi *et al.*[32]. Dyslipidemia was defined as having one or more of the following three indexes: TG≥1.7 mmol/L, TC≥5.18 mmol/L, and HDL-C≤ 1.04 mmol/L. An elevated glucose level was defined as fasting plasma glucose≥5.6 mmol/L.

Overweight and obesity were defined using age- and sex-specific BMI cut-off points developed by the Working Group for Obesity in China[33].

Statistical Analysis

Optimal waist circumference for predicting cardiovascular disease risk factors was analyzed based on the pooled original data.

According to the waist circumference percentiles developed by Ji *et al.*[26], the subjects were divided into different waist circumference groups by every 5th percentile. Mean values and standard deviation of the cardiovascular disease risk profiles and percentage of subjects with cardiovascular disease risk factors were calculated by sex and by waist groups, to predict the point where the mean value and prevalence rose steeply.

Receive-operating characteristic analysis (ROC) was employed to derive optimal age- and sex-specific waist circumference references for predicting these cardiovascular disease risk factors. The optimal cut-off value was denoted by the value that had the largest sum of sensitivity and specificity[34]. In addition, the percentage of subjects with cardiovascular

TABLE 1

Basic Information of the Pooled Data Used in the Present Study

	Sample Size	Age Range	Measurements						
			Waist Circumference	Blood Pressure	Glucose	HDL-C	TG	TC	LDL-C
Sung RYT[22]	14 090	7-17	WHO Standard*	Datascope Accutorr Plus†	——	——	——	——	——
Meng LH[23]	21 299	7-17	WHO Standard*	Manual Mercury Desk Sphygmomanometer¶	Glucose Oxidase	Homogeneous Method	Enzymatic Methods	Enzymatic Methods	Homogeneous Method
Yan W[24]	4 261	7-17	1-2cm Above Navel	Manual Mercury Desk Sphygmomanometer¶	Glucose Oxidase	PEGME	Enzymatic Methods	Enzymatic Methods	Homogeneous Method
Huang GM[25]	6 582	7-17	WHO Standard*	Manual Mercury Desk Sphygmomanometer¶	——	——	——	——	——
Zhang SW[27]	1 089	7-15	WHO Standard*	Manual Mercury Desk Sphygmomanometer¶	Glucose Oxidase	PEGME	Enzymatic Methods	Enzymatic Methods	Homogeneous Method
Yin ZD[28]	926	14-16	WHO Standard*	Manual Mercury Desk Sphygmomanometer¶	Glucose Oxidase	PEGME	Enzymatic Methods	Enzymatic Methods	Homogeneous Method
Wang L[29]	6 869	15-18	WHO Standard*	Manual Mercury Desk Sphygmomanometer¶	Glucose Oxidase	Homogeneous Method	GPO-PAP	CHOD-PAP	Friedewald Formula‡
Li LZ[30-31]	6 201	7-12	WHO Standard*	Manual Mercury Desk Sphygmomanometer¶	Glucose Oxidase	Homogeneous Method	GPO-PAP	CHOD-PAP	Friedewald Formula‡
Liu A[32]	4 581	7-11	WHO Standard*	Manual Mercury Desk Sphygmomanometer¶	Glucose Oxidase	Homogeneous Method	GPO-PAP	CHOD-PAP	Friedewald Formula‡
Total (N)	65 898	7-18	65 898	65 898	12 544	11 683	11 683	11 683	11 683

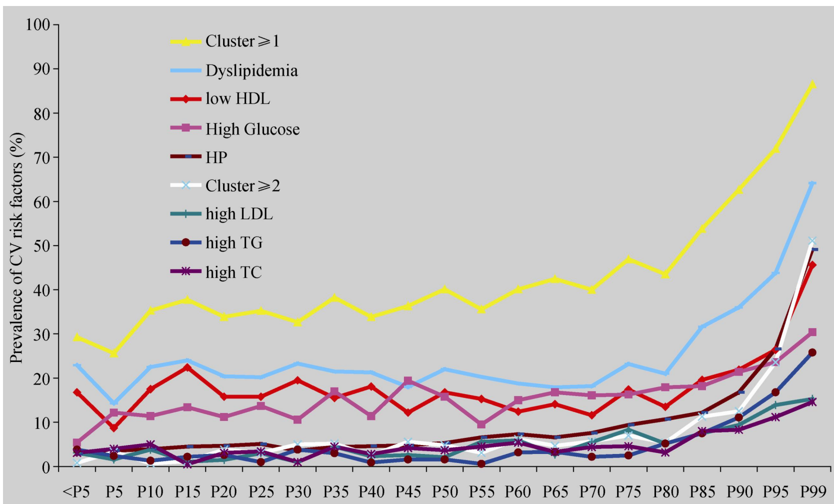
Note. * Midpoint between the bottom of the rib cage and the top of the iliac crest at the end of exhalation. ¶ Blood pressure was measured in the seated position after 5 min rest with a standard manual mercury desk sphygmomanometer by trained individual according to standard method. † Blood pressure (BP) was measured oscillometrically using the Datascope Accutorr Plus. ‡ LDL-C= TC – HDL-C – TG /2.2. 11 193 subject had full data of blood pressure, lipid, and glucose (for clustering).

risk factors were compared between children whose waist circumference below or above the optimal cut-off values. Odds ratios were calculated using logistic regressions adjusting for potential confounding factors. The odds of high blood pressure was further compared between different waist circumference groups after stratified by BMI category as recommended by the Working Group of Obesity in China (WGOC)[33]. Age and data source were included in the model as covariance. Sex was further adjusted for in the model stratified by BMI category.

RESULTS

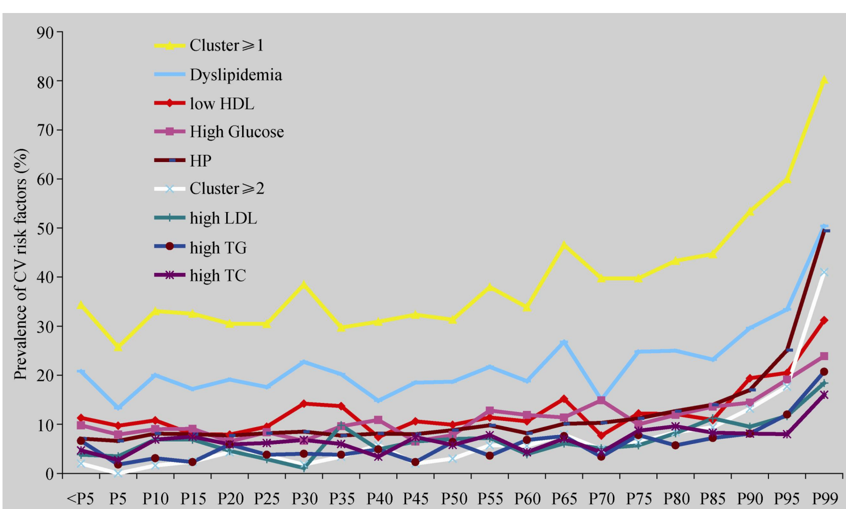
Data of children aged 7-18 years from the 9 studies were pooled, including a total of 65 898 subjects consisting of 33 570 boys and 32 328 girls.

The mean values and the prevalence of cardiovascular disease risk factors by sex and waist circumference groups are shown in Table 2 (boy) and Table 3 (girl). Slight increasing trends of cardiovascular diseases risk factors were found starting from the 75th percentile, while remarkably increasing trends from the 90th percentile (Figs. 1 and 2).



Waist circumference (percentile)

FIG. 1. Prevalence of cardiovascular risk factors according to waist circumference percentiles among boys.



Waist circumference (percentile)

FIG. 2. Prevalence of cardiovascular risk factors according to waist circumference percentiles among girls.

TABLE 2

Mean±SD and Prevalence of Cardiovascular Risk Factors according to Waist Circumference Percentiles among Boys

	Waist Circumference Percentile											
	<50th	50th-	55th-	60th-	65th-	70th-	75th-	80th-	85th-	90th-	95th-	⩾99th
Glucose												
N	2 031	215	199	220	191	199	263	262	435	837	1 579	286
Glucose (mmol/L)	4.87±0.70	4.97±0.60	4.92±0.53	4.97±0.66	5.05±0.61	5.04±0.52	5.04±0.93	5.04±0.57	5.03±0.59	5.10±0.63	5.14±0.74	5.20±0.81
High Glucose (%)	12.9	15.8	9.5	15.0	16.8	16.1	16.3	17.9	18.2	21.4	23.6	30.4
Blood Pressure (BP)												
N	16 561	1 491	1 403	1 325	1 295	1 211	1 314	1 390	1 799	2 378	2 937	466
Systolic BP (mmHg)	104.2±11.4	106.7±11.2	106.4±11.4	107.4±11.4	107.2±11.4	108.0±11.2	108.1±11.0	109.1±11.4	109.9±11.4	112.0±11.8	115.8±12.9	126.6±15.3
High SBP (%)	1.9	2.9	2.8	3.3	3.5	4.3	5.3	6.1	7.6	10.6	19.4	42.5
Diastolic BP	64.8±8.8	66.1±8.5	66.3±8.6	66.7±9.0	66.7±8.8	67.1±8.6	67.1±8.7	67.5±8.6	68.4±8.7	69.4±9.0	71.7±9.3	77.7±9.8
High DBP (%)	2.9	3.0	4.7	5.3	4.5	4.7	6.1	7.1	8.3	10.4	15.9	30.3
High BP	4.2	5.3	6.6	7.3	6.6	7.6	9.4	10.7	12.2	16.8	26.6	49.1
Lipid												
N	1 814	191	177	186	184	181	241	252	424	836	1 564	287
TG (mmol/L)	0.78±0.36	0.79±0.32	0.74±0.27	0.84±0.38	0.81±0.35	0.84±0.35	0.82±0.34	0.86±0.40	0.99±0.71	1.06±0.51	1.22±0.65	1.41±0.67
(%)	2.2	1.6	0.6	3.2	3.3	2.2	2.5	5.2	7.5	11.1	16.8	25.8
TC (mmol/L)	3.49±0.83	3.64±0.86	3.69±0.84	3.68±0.81	3.71±0.83	3.86±0.83	3.83±0.82	3.93±0.73	4.07±0.80	4.12±0.75	4.24±0.78	4.30±0.85
(%)	3.1	3.7	4.5	5.4	3.3	4.4	4.6	3.2	8.0	8.3	11.2	14.6
HDL (mmol/L)	1.40±0.38	1.41±0.39	1.41±0.37	1.40±0.34	1.40±0.34	1.44±0.34	1.41±0.39	1.40±0.35	1.34±0.37	1.29±0.33	1.23±0.31	1.10±0.31
(%)	16.5	16.8	15.3	12.4	14.1	11.6	17.4	13.5	19.6	21.9	26.4	45.6
LDL (mmol/L)	1.79±0.70	1.92±0.68	2.01±0.74	2.00±0.72	2.00±0.75	2.12±0.77	2.18±0.77	2.24±0.72	2.35±0.75	2.47±0.68	2.61±0.72	2.71±0.78
(%)	2.4	2.1	5.6	5.9	2.7	5.5	8.3	5.2	7.5	9.4	13.9	15.3
Dyslipidemia (%)	21.0	22.0	20.3	18.8	17.9	18.2	23.2	21.0	32.6	36.0	43.8	64.1
Cluster*												
N**	17.7	187	163	177	172	175	228	239	407	806	1 537	282
⩾1 (%)	34.2	40.1	35.6	40.1	42.4	40.0	46.9	43.5	53.8	62.7	71.9	86.5
⩾2 (%)	3.3	4.8	3.1	6.2	4.7	5.7	7.0	5.4	11.3	12.5	23.6	51.1

Note. *Cluster of risk factors included high blood pressure, high glucose level and/or dyslipidemia; **N was number of subjects who had all 3 risk factors measured.

TABLE 3

Mean±SD and Prevalence of Cardiovascular Risk Factors according to Waist Circumference Percentiles among Girls

	Waist Circumference Percentile											
	<50th	50th-	55th-	60th-	65th-	70th-	75th-	80th-	85th-	90th-	95th-	≥99th
Glucose												
N	1 906	205	195	244	211	262	251	295	374	584	952	348
Glucose (mmol/L)	4.81±0.58	4.84±0.56	4.95±0.57	4.86±0.56	4.89±0.90	4.95±0.78	4.87±0.54	4.89±0.58	4.97±0.63	4.99±0.67	5.03±0.79	5.17±0.98
High Glucose (%)	8.4	7.8	12.8	11.9	11.4	14.9	10.0	11.9	13.6	14.4	19.1	23.9
Blood Pressure (BP)												
N	16 254	1 495	1 362	1 524	1 378	1 465	1 454	1 488	1 514	1 796	1 977	621
Systolic BP (mmHg)	102.0±10.7	102.9±10.0	103.3±10.1	102.7±10.1	103.0±10.2	103.9±10.2	104.6±10.5	104.6±10.2	105.6±10.5	107.0±10.5	109.7±11.2	117.1±14.0
High SBP (%)	5.0	5.6	6.1	5.6	6.7	6.6	8.7	8.6	10.0	12.9	20.2	40.4
Diastolic BP	64.2±8.4	65.0±8.1	65.5±8.1	64.6±7.9	65.3±8.4	65.6±8.1	65.8±8.1	66.1±8.1	66.3±8.0	67.8±8.0	69.4±8.5	74.3±9.6
High DBP (%)	4.3	4.7	6.2	3.8	5.8	5.9	5.6	7.5	7.9	10.2	14.4	31.2
High BP	7.8	8.8	9.8	8.2	10.1	10.3	11.2	12.7	14.0	17.0	25.1	49.4
Lipid												
N	1663	171	166	207	198	234	230	280	349	557	948	343
TG (mmol/L)	0.89±0.40	0.94±0.45	0.90±0.34	0.99±0.64	0.94±0.42	0.90±0.37	0.97±0.46	0.97±0.41	0.99±0.49	1.01±0.45	1.15±0.57	1.35±0.79
(%)	3.8	6.4	3.6	6.8	7.6	3.4	7.8	5.7	7.2	8.1	12.0	20.7
TC (mmol/L)	3.79±0.83	3.81±0.85	3.85±0.89	3.85±0.91	3.88±0.86	3.87±0.75	3.93±0.83	4.04±0.86	4.10±0.78	4.05±0.78	4.16±0.76	4.36±0.86
(%)	5.9	5.8	7.8	4.3	7.1	4.3	8.7	9.6	8.3	8.1	8.0	16.0
HDL (mmol/L)	1.45±0.34	1.49±0.35	1.45±0.36	1.42±0.34	1.41±0.36	1.42±0.29	1.41±0.35	1.43±0.33	1.40±0.36	1.32±0.33	1.27±0.29	1.20±0.31
(%)	10.3	9.9	11.4	10.6	15.2	7.7	12.2	12.1	10.9	19.4	20.5	31.2
LDL (mmol/L)	2.05±0.76	2.06±0.76	2.08±0.80	2.08±0.85	2.16±0.77	2.18±0.68	2.21±0.73	2.29±0.78	2.45±0.77	2.41±0.71	2.52±0.69	2.71±0.76
(%)	5.2	7.0	7.2	3.9	6.1	5.1	5.7	8.2	11.2	9.5	11.7	18.4
Dyslipidemia (%)	18.4	18.7	21.7	18.8	26.8	15.0	24.8	25.0	23.2	29.6	33.4	50.4
Cluster*												
N	1 568	166	158	195	189	224	219	261	329	538	927	339
≥1 (%)	31.9	31.3	38.0	33.9	46.5	39.7	39.7	43.3	44.7	53.4	60.0	80.2
≥2 (%)	2.9	3.0	5.7	5.6	7.9	4.9	6.4	8.4	9.4	13.2	17.7	41.0

Note. *Cluster include high blood pressure, high glucose level and/or dyslipidemia.

Table 4 showed the results from ROC analysis. The optimal waist circumference thresholds for predicting high blood pressures were at the 75th percentile for both boys and girls, which was at the 90th percentiles for detecting at least two of the above three cardiovascular disease risk factors. The corresponding waist circumference thresholds of the 75th and the 90th percentile are listed in Table 5.

TABLE 4

Results of ROC Curve Analysis Predicting Optimal Waist Circumference for Cardiovascular Risk Factors

	Area Under the Curve (95% CI)	Percentile	Sensitivity (%)	Specificity (%)
Boys				
High Blood Pressure	0.720 (0.710-0.731)	P75	62.4	72.5
High Glucose	0.597 (0.580-0.614)	P85	58.9	56.0
Dyslipidemia	0.645 (0.631-0.660)	P85	66.1	58.6
High TG	0.741 (0.721-0.761)	P90	79.4	61.0
High TC	0.656 (0.630-0.681)	P85	73.4	52.7
Low HDL	0.596 (0.578-0.614)	P90	55.3	60.9
High LDL	0.684 (0.661-0.706)	P90	69.4	59.8
*Cluster≥1	0.689 (0.676-0.703)	P85	64.5	66.5
*Cluster≥2	0.759 (0.742-0.777)	P90	77.7	61.9
Girls				
High Blood Pressure	0.635 (0.625-0.646)	P75	46.2	75.0
High Glucose	0.609 (0.587-0.631)	P85	53.1	63.4
Dyslipidemia	0.613 (0.596-0.631)	P90	48.0	70.0
High TG	0.657 (0.628-0.685)	P90	56.4	67.2
High TC	0.574 (0.544-0.603)	P75	51.2	54.0
Low HDL	0.616 (0.594-0.638)	P90	52.0	68.4
High LDL	0.625 (0.597-0.652)	P85	60.0	60.6
*Cluster≥1	0.651 (0.636-0.666)	P90	48.1	75.4
*Cluster≥2	0.751 (0.730-0.773)	P90	69.6	68.8

Note. *Cluster of high blood pressure, high glucose, dyslipidemia.

TABLE 5

Waist Circumference Threshold (cm) of the Optimal Cut-off Points (75th Percentile and 90th Percentile)[26]

Age	Boys		Girls	
(yrs)	P75	P90	P75	P90
7-	58.4	63.6	55.8	60.2
8-	60.8	66.8	57.6	62.5
9-	63.4	70.0	59.8	65.1
10-	65.9	73.1	62.2	67.8
11-	68.1	75.6	64.6	70.4
12-	69.8	77.4	66.8	72.6
13-	71.3	78.6	68.5	74.0
14-	72.6	79.6	69.6	74.9
15-	73.8	80.5	70.4	75.5
16-	74.8	81.3	70.9	75.8
17-	75.7	82.1	71.2	76.0
18-	76.8	83.0	71.3	76.1

In comparison with children whose waist circumference below the 75th percentile, the likelihood of having two cardiovascular diseases risk factors doubled (OR=2.2, and 95% CI: 1.6 to 3.0) among children with waist circumference between the 75th and the 90th percentiles, and increased by 6 times (Boys: 6.7: 5.3-8.4; Girls: 6.2: 4.9-7.8) among children with waist circumference above the 90th percentile (Table 6). The increasing trend of high blood pressure with waist circumference remained significant after having been stratified by BMI category (Fig. 3).

DISCUSSION

The value and growth pattern of waist circumference vary among different populations. The waist circumference of Chinese children was smaller than that of their counterparts from the United States[19], Australia[35], and the Netherlands[36], bigger than their Japanese counterparts[21] and different from their counterparts from Canada[37], Britain[38], and Turkey[20]. However, the lower waist circumference of Chinese children does not mean the lower risk to cardiovascular diseases. Since the risk factors for cardiovascular diseases at a given BMI are generally higher among Asians, as compared with the Western population[13, 39], it is assumed that the same is with the case of waist circumference, given a positive correlation between WC and body fat percentage[14]. This hypothesis is supported by the results of our study using the pooled data. The likelihood of having multiple risk factors for cardiovascular disease doubled among children with a waist circumference between the 75th and the 90th percentiles, which increased by six times among children whose waist circumference was higher than the 90th percentile, when compared with children with lower waist circumference (Table 6).

TABLE 6

Comparisons in Prevalence and Odds Ratio of Cardiovascular Risk Factors among Children Whose Waist Circumference below or above the Optimal Cut-off Values

	Boys			Girls		
Waist Circumference percentile	<P75	P75-P90	≥P90	<P75	P75-P90	≥P90
High Blood Pressure						
N	23 286	4 503	5 781	23 478	4 456	4 394
%	4.9	10.9	24.4	8.3	12.7	25.3
Odds Ratio*	1.0	2.4	6.3	1.0	1.7	4.2
(95% CI)		(2.1-2.7)	(5.8-6.9)		(1.5-1.8)	(3.7-4.3)
High Glucose						
N	3 055	960	2 702	3 023	920	1 884
%	13.5	17.6	23.6	9.7	12.1	18.5
Odds Ratio	1.0	1.3	1.9	1.0	1.3	2.1
(95% CI)		(1.1-1.6)	(1.6-2.2)		(1.0-1.6)	(1.8-2.5)
Dyslipidemia						
N	2 735	917	2 688	2 640	859	1 849
%	20.5	26.5	43.6	19.0	24.2	35.4
Odds Ratio	1.0	1.7	3.8	1.0	1.4	2.5
(95% CI)		(1.4-2.0)	(3.3-4.3)		(1.2-1.7)	(2.2-2.9)
Cluster≥1						
N	2 581	874	2 625	2 500	809	1 804
%	36.1	49.2	70.6	34.2	42.9	61.8
Odds Ratio	1.0	1.6	3.9	1.0	1.4	3.0
(95% CI)		(1.4-1.9)	(3.4-4.4)		(1.2-1.7)	(2.6-3.4)
Cluster≥2						
N	2 581	874	2 625	2 500	809	1 804
%	3.8	8.6	23.1	3.8	8.3	20.7
Odds Ratio	1.0	2.2	6.7	1.0	2.2	6.2
(95% CI)		(1.6-3.0)	(5.3-8.4)		(1.6-3.0)	(4.9-7.8)

Note. *Logistic regression, adjusted age, sex, and data sources.

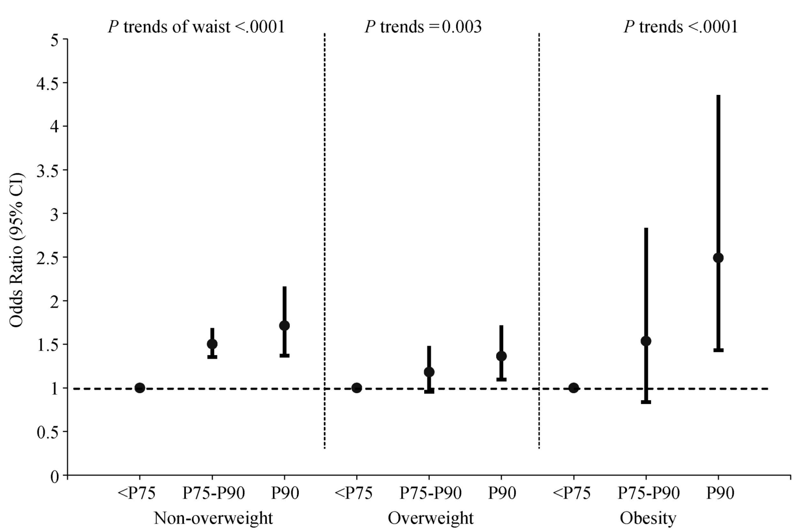


FIG. 3. Odds ratio of high blood pressure of different optimal waist circumference cut-off points stratified by BMI category.

Among adults, obesity classification criteria are often defined as the points that are possible to identify individuals and groups at increased risk of morbidity and mortality (WHO)[40]. The classification of obesity during childhood or adolescence is further complicated, owing to the fact that children have less diseases related to obesity than adults, and the association between childhood obesity and adulthood health risk may be mediated through adulthood obesity, which is associated both with childhood obesity and adulthood disease[41]. Therefore, among children, the obesity criteria are always based either on modified adult cut-off points[36, 42]or a percentile cut-off point where the health related risk factors starts to rise steeply according to the cross-sectional data[43, 46].

The results of our study indicated that, starting from the 75th percentile of waist circumference, the prevalence of high blood pressure, dyslipidemia, and elevated glucose as well as the clustering of these risk factor start to increase along with the increase of WC, which is substantially elevated from the 90th percentile (Figs.1-2). The above findings were confirmed by the ROC results that the optimal WC thresholds for predicting high blood pressure were at the 75th percentile, and at the 90th percentile for detecting at least two cardiovascular diseases risk factors. ROC curve method was also used in other populations, including those from the USA[43-44], Spain[45], and Iran[46], to detect the optimal waist circumference of children for predicting cardiovascular disease risk factors.

As an essential component of pediatric metabolic syndrome, waist circumference cut-off points were always developed based on modified adult criteria in previous studies. Based on the adult ATP III criteria for metabolic syndrome, waist circumference cut-off point was 102 cm for males and 88 cm for females, which was the 72nd and the 53rd percentile of adults, respectively[47]. Then, de Ferranti *et al.*[42] chose the 75th percentile of waist circumference as the cut-off points for pediatric metabolic syndrome. Also based on adult criteria, a cut-off point of 1.3 standard deviation score was chosen for waist circumference in Dutch children[36]. In China, as recommended by WGOC[48], the waist circumference cut-off points for predicting increased risk of cardiovascular disease risk factors among adults are 85 cm for male and 80 cm for females, and 95 cm for males and 90 cm for females for predicting substantially increased risk. The waist circumference of 85 cm for males, 95 cm for males, 80 cm for females, 90 cm for females correspond to the 75th percentile for males, the 91th for males, the 76th for females, the 94th for females, females respectively among Chinese adults aged 18-45 years, and the 68th for males, the 91th for males, the 56th for females, the 86th for females, respectively among adults aged 45-60 years old (Based on the 2002 China National Nutrition and Health Survey, unpublished). The evidences from the modified adult criteria support the results that the 75th and the 90th percentile of waist circumference should be the optimal cut-off points for predicting an increased and a substantially increased risk of cardiovascular diseases risk factors for children.

Ford *et al.*[49] listed 46 definitions of pediatric metabolic syndrome in their review paper, among them 14 definitions used the 90th percentile by sex and age, or only by sex, or further by ethnicity, as cut-off points for waist circumference, including the most commonly used definition published by Cook *et al.*[18]. However, the reasons for choosing the 90th percentile have not been fully discussed. The International Diabetes Federation also used the 90th percentile as a cutoff for waist circumference in the new pediatric metabolic syndrome definition[17]. They also mentioned that reassessment was needed when more data were available. The present results support the usefulness of the 90th percentile of waist circumference for predicting multiple cardiovascular diseases risk factors among children. However, the lower screening cut-off points, such as the 75th percentile or the 80th percentile, should not be excluded when they are considered as criteria for increased risk of cardiovascular diseases in future intervention or prevention studies. Because the onset of diabetes among Asian people is not only at lower BMI but also at younger age[50], it is very important to initiate the prevention starting from children whose risk of CV starts to increase (WC above 75th).

It is well documented that using waist circumference within BMI category is better for identifying individuals with higher levels of abdominal fat than would be expected on the basis of BMI alone[51]. Among obese adolescents with similar BMIs, insulin sensitivity is lower in those with more visceral fat than in those with less fat[52]. Current paper indicates that, within the BMI category, waist circumference is powerful to detect the children with higher likelihood of high blood pressure.

Our present study used the largest data set in the world to study the optimal waist circumference cut-off points for predicting cardiovascular disease risk factors among children. Several weakness of our study should be mentioned when interpreting the results. Firstly, it is a cross-sectional study, and can not establish a causal relationship between high waist circumference and high risk of cardiovascular diseases. Secondly, the measurements of waist circumference are different among the nine studies pooled, which may serve as a confounder. We try to control its effect by including the variable of data source in the model of our analysis.

In summary, the mean value and prevalence of cardiovascular diseases risk factors start to increase at the 75th percentile and increase steeply from the 90th percentile based on the current large pooled cross-sectional data. The results for ROC analysis and the values of corresponding percentiles to adult cut-off points of waist circumference also support these two points. So we suggest that the 75th and the 90th percentile of waist circumference may be used as the cut-off points for predicting an increased and a substantially increased risk of cardiovascular diseases risk factors among children.

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REFERENCES

1. Lobstein T, Baur L, Uauy R (2004). Obesity in children and young people: a crisis in public health. *Obes Rev* **5**(Suppl 1), 16-22.
2. Hossain P, Kawar B, El Nahas M (2007). Obesity and diabetes in the developing world--a growing challenge. *N Engl J Med* **356**, 213-215.
3. Li Y, Schouten E G, Cui Z, *et al.* (2008). Obesity prevalence and time trends among Chinese youngster, 1982-2002. *Asia Pacific J Clin Nutr* **17**, 131-137.
4. Freedman D S, Katzmarzyk P T, Dietz W H, *et al.* (2009). Relation of body mass index and skinfold thicknesses to cardiovascular disease risk factors in children: the Bogalusa Heart Study. *Am J Clin Nutr* **90**, 210-216.
5. Plachta-Danielzik S, Landsberg B, Johannsen M, *et al.* (2008). Association of different obesity indices with blood pressure and blood lipids in children and adolescents. *Br J Nutr* **100**, 208-218.
6. Weiss R, Dziura J, Burgert T S, *et al.* (2004) Obesity and the metabolic syndrome in children and adolescents. *N Engl J Med* **350**, 2362-2674.
7. Li Y, Yang X, Zhai F, *et al.* (2008). Childhood obesity and its health consequence in China. *Obes Rev* **9**(Suppl 1), 82-86.
8. Verhulst S L, Van Gaal L, De Backer W, *et al.* (2008). The prevalence, anatomical correlates and treatment of sleep-disordered breathing in obese children and adolescents. *Sleep Med Rev* **12**, 339-346.
9. Daniels S R, Arnett D K, Eckel R H, *et al.* (2005). Overweight in children and adolescents: pathophysiology, consequences, prevention, and treatment. *Circulation* **111**, 1999-2012.
10. Berenson G S, Srinivasan S R, Bao W, *et al.* (1998). Association between multiple cardiovascular risk factors and atherosclerosis in children and young adults. The Bogalusa Heart Study. *N Engl J Med* **338**, 1650-1656.
11. Freedman D S, Khan L K, Dietz W H, *et al.* (2001). Relationship of childhood obesity to coronary heart disease risk factors in adulthood: the Bogalusa Heart Study. *Pediatrics* **108**, 712-718.
12. McCrindle B W (2006). Will childhood obesity lead to an epidemic of premature cardiovascular disease? *Evid Based Cardiovasc Med* **10**, 71-74.
13. Wang J, Thornton J C, Russell M, *et al.* (1994). Asians have lower body mass index (BMI) but higher percent body fat than do whites: comparisons of anthropo-metric measurements. *Am J Clin Nutr* **60**, 23-28.
14. Ball G D, Huang T T, Cruz M L, *et al.* (2006). Predicting abdominal adipose tissue in overweight Latino youth. *Int J Pediatr Obes* **1**, 210-216.
15. Lee S, Bacha F, Arslanian S A (2006). Waist circumference, blood pressure, and lipid components of the metabolic syndrome. *J Pediatr* **149**, 809-816.
16. Zhang C, Rexrode K M, van Dam R M, *et al.* (2008). Abdominal obesity and the risk of all-cause, cardiovascular, and cancer mortality: sixteen years of follow-up in US women. *Circulation* **117**, 1658-1667.
17. Zimmet P, Alberti G, Kaufman F, *et al.* (2007). The metabolic syndrome in children and adolescents. *Lancet* **369**, 2059-2061.
18. Cook S, Weitzman M, Auinger P, et al. (2003). Prevalence of a metabolic syndrome phenotype in adolescents: findings from the third National Health and Nutrition Examination Survey, 1988-1994. *Arch Pediatr Adolesc Med* **157**, 821-827
19. Fernandez J R, Redden D T, Pietrobelli A, *et al.* (2004). Waist circumference percentiles in nationally representative samples of African-American, European-American, and Mexican-American children and adolescents. *J Pediatr* **145**, 439-444.
20. Hatipoglu N, Ozturk A, Mazicioglu M M, *et al.* (2008). Waist circumference percentiles for 7- to 17-year-old Turkish children and adolescents. *Eur J Pediatr* **167**, 383-389.
21. Inokuchi M, Matsuo N, Anzo M, *et al.* (2007). Age-dependent percentile for waist circumference for Japanese children based on the 1992-1994 cross-sectional national survey data. *Eur J Pediatr* **166**, 655-661.
22. Sung R Y T, So H K, Choi K C, *et al.* (2008). Waist circumference and weight-to-height ratio of Hong Kong Chinese children. BMC Public Health **8**, 324. doi:10.1186/1471-2458-8-324
23. Meng L H, Mi J, Cheng H, *et al.* (2007). Use of waist circumference and waist-to-height ratio to access central obesity in children and adolescents. *Chin J Evid Based Pediatr* **2**, 245-251.
24. Yan W, Yao H, Dai J H, *et al.* (2008). Waist circumference cutoff points in school-aged Chinese han and uygur children. *Obesity* **16**, 1687-1692.
25. Huang G M, Xiong F, Zeng Y (2009). Study on the relationship of waist circumference, waist-to-height ratio, Waist-hip ratio and blood pressure in children and adolescents. *J Chong Qing Med Univ* **34**, 360-365. (In Chinese)
26. Ji C, Ma G, Sung R Y T, *et al.* (2010). Waist Circumference Distribution of Chinese School-age Children and Adolescents *Biomed Environ Sci* **23**(1), 21-31.
27. Zhang S W, Ma J, Wu S X, *et al.* (2007). Fasting glucose and

serum lipids level of normal-weight, overweight and obese children in Beijing. *Chin J Sch Health* **28**, 1087-1089. (In Chinese)

28. Yin Z D, Ma J, Xu Y Q, *et al.* (2005). The relationship between the BMI, WHR and serum lipid levels in adolescents. *Chin J Sch Health* **26**, 724-725. (In Chinese)
29. Wang L (2005) Report of China Nationwide Nutrition and Health Survey 2002 (1): Summary Report. Beijing, People's Medical Publishing House, 18-45. (In Chinese)
30. Li L Z, Hu X Q, Cui Z H, *et al.* (2007). Study on the relation between anthropometric parameters and lipids profiles. *Zhong Hua Liu Xing Bing Xue Za* Zhi **28**, 734-737. (In Chinese)
31. Du S, Li Y, Cui Z, *et al.* (2007). The Relationship between Obesity and Blood Pressure among Children Living in Urban Area Beijing. *Zhong Guo Man Xing Bing Yu Fang Yu Kong Zhi* **15**, 213-215. (In Chinese)
32. Xi B, Mi J, Wang L, *et al.* (2008). Family aggregation of primary hypertension among children and adolescents in Beijing. *Chin J Ep idemiol* **29**, 819-823. (In Chinese)
33. Group of China Obesity Task Force (2004) Body mass index reference norm for screening overweight and obesity in Chinese children and adolescents. *Zhong Hua Liu Xing Bing Xue Za Zhi* **25**, 97-102. (In Chinese)
34. Cole T J, Green P J. (1992). Smoothing reference centile curves: the LMS method and penalized likelihood. *Stat Med* **11**, 1305-1319.
35. Eisenmann J C (2005). Waist circumference percentiles for 7- to 15-year-old Australian children. *Acta Paediatr* **94**, 1182-1185.
36. Fredriks A M, van Buuren S, Fekkes M, *et al.* (2005). Are age references for waist circumference, hip circumference and waist-hip ratio in Dutch children useful in clinical practice? *Eur J Pediatr* **164**, 216-222.
37. Katzmarzyk P T (2004). Waist circumference percentiles for Canadian youth 11-18 y of age. *Eur J Clin Nutr* **58**, 1011-1015.
38. McCarthy H D, Jarrett K V, Crawley H F (2001). The development of waist circumference percentiles in British children aged 5.0-16.9 y. *Eur J Clin Nutr* **55**, 902-907.
39. WHO expert consultation (2004). Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet* **363**, 157-63.
40. World Health Organization (1997). Obesity: Preventing and managing the global epidemic. Report of a WHO consultation on obesity. June 3-5, 1997. WHO/NUT/NCD/98.1. i–xv. 1-178. 998. Geneva Switzerland. World Health organization. http://whqlibdoc.who.int/hq/1998/WHO_NUT_NCD_98.1_(p1-158).pdf.
41. Cole T J, Bellizzi M C, Flegal K M, *et al.* (2000). Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ* **320**, 1240-1243.
42. de Ferranti S D, Gauvreau K, Ludwig D S, *et al.* (2004). Prevalence of the metabolic syndrome in American adolescents: findings from the Third National Health and Nutrition Examination Survey. *Circulation* **110**, 2494-2497
43. Katzmarzyk P T, Srinivasan S R, Chen W, *et al.* (2004). Body mass index, waist circumference, and clustering of cardiovascular disease risk factors in a biracial sample of children and adolescents. *Pediatrics* **114**, e198-205.
44. Messiah S E, Arheart K L, Lipshultz S E, *et al.* (2008). Body mass index, waist circumference, and cardiovascular risk factors in adolescents. *J Pediatr* **153**, 845-850.
45. Moreno L A, Pineda I, Rodríguez G, *et al.* (2002). Waist circumference for the screening of the metabolic syndrome in children. *Acta Paediatr* **91**, 1307-1312.
46. Kelishadi R, Gheiratmand R, Ardalan G, *et al.* (2007). Association of anthropometric indices with cardiovascular disease risk factors among children and adolescents: CASPIAN Study. *Int J Cardiol* **117**, 340-348.
47. Zhu S, Wang Z, Heshka S, *et al.* (2002). Waist circumference and obesity associated risk factors among whites in the third National Health and Nutrition Examination Survey: clinical action thresholds. *Am J Clin Nutr* **76**, 743-749.
48. Chen C, Lu F C, Department of Disease Control Ministry of Health, PR China (2004). The guidelines for prevention and control of overweight and obesity in Chinese adults. *Biomed Environ Sci* **17** (**Suppl**), 1-36.
49. Ford E S, Li C (2008). Defining the metabolic syndrome in children and adolescents: will the real definition please stand up? *J Pediatr* **152**, 160-164.
50. Chan J C, Malik V, Jia W, *et al.* (2009). Diabetes in Asia: epidemiology, risk factors, and pathophysiology. *JAMA* **27**, 2129-2140.
51. National Heart, Lung, and Blood Institute (1998). Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. *Obes Res* **6**, S51-S210.
52. Bacha F, Saad R, Gungor N, *et al.* (2006). Are obesity-related metabolic risk factors modulated by the degree of insulin resistance in adolescents? *Diabetes Care* **29**, 1599-1604.

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