Research Article

Waist circumference, health-related physical fitness, and cardiovascular disease risk factors in Chinese adolescents

Abstract

This study aimed to examine differences in CVD risk factors across four cross-tabulated groups according to health-related physical fitness index (PFI, composite index of standing long jump, 50-m test, and 800- or 1000-m run/walk) and waist circumference (WC) in Guangzhou youth. Participants comprised 588 males and 579 females aged 11–18years from Guangzhou, China. They were cross-tabulated into four groups according to WC and PFI, namely, Low-WC/High-PFI, High-WC/Low-PFI, Low-WC/Low-PFI, and High-WC/High-PFI. A CVD risk score was derived from six established CVD risk factors, i.e., blood pressure (BP), triglycerides (TG), fasting total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), and TC: HDL-C. For both genders, lower BP values were observed in the Low-WC group compared with the High-WC group with the same fitness level ($p<0.05$). In boys, participants in the Low-WC/Low-PFI group also had lower BP than those in the High-WC/High-PFI group ($p<0.05$). Lower TC, LDL-C, TC: HDL-C, and higher HDL-C were also found in the Low-WC groups than in the High-WC groups in boys ($p<0.05$). A general trend of lower blood lipids and glucose for both boys and girls in the High-PFI group compared with the Low-PFI group was also observed. Higher CVD risk scores were only observed in the High-WC group compared with the Low-WC group with the same PFI level for boys ($p<0.05$). We can concluded that clustering of CVD risk factors was inversely related to WC, and physical fitness may play a positive effect on reducing the hazards of abdominal obesity.

Keywords: waist circumference, physical fitness, cardiovascular disease, children, adolescence

Volume 5 Issue 2 - 2017

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Received: October 08, 2016 | **Published:** February 08, 2017

Abbreviations: CVD, cardiovascular disease; BMI, body mass index; PFI, physical fitness index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; MAP, mean arterial pressure; TG, triglyceride; TC, total cholesterol; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; CRF, cardio respiratory fitness; MS, muscular strength; SP-AG, speed-agility; LF, low-fat; HF, high-fat; LP, low-PFI; HP, high-PFI

Introduction

Cardiovascular disease (CVD) remains the leading cause of death in China and worldwide.[1] In 2010, the percentage of ideal cardiovascular health in Chinese adults was estimated at 0.2% (0.1% in men and 0.4% in women).[2] Although the clinical manifestations of CVD occur in adulthood, the atherosclerotic process begins during childhood.[3] Furthermore, certain early life exposures, such as childhood obesity, may lead to later CVD irrespective of the level of adult exposure.[4] In adult populations, overweight and low levels of cardio respiratory fitness are independently associated with CVD morbidity and mortality.[5] In children and adolescents, however, the relationship between body fatness and CVD risk factors is moderated by cardio respiratory fitness.[6,7] Given that CVD is a lifelong process, such intergenerational differences in the etiology of risk after confirmation would have important implications for the prevention of CVD at different stages of life.[8]

Eisenmann and colleagues have consistently shown that cardio respiratory fitness attenuates the association between percent body fat or body mass index (BMI) and CVD risk factor profile in children and adolescents (the fat-fit hypothesis).[9–11] However, a major limitation in these studies was the use of the single fitness measurement to represent health-related fitness level. Despite a lack of consensus on criterion measures of physical fitness in China, the concept of health-related fitness is operational zed as a composite of cardio respiratory endurance, abdominal muscular strength and endurance, lower back/upper thigh flexibility, and body composition.[12] Single fitness measurement may not completely reflect the overall quality of physical fitness. A composite physical fitness index (PFI) based on different measurements of fitness may be a better indicator to reflect the overall physical fitness level.[13] Population-based estimates of fitness based on comprehensive fitness testing are scarce in China, especially among children. In addition, a greater waist circumference (WC) is particularly linked to metabolic syndrome in adults[14] and in children and adolescents.[15] Thus, WC may be a better predictor of type 2 diabetes and CVD than body fat percentage and BMI. Therefore, the present study aimed to explore further the fat-fit hypothesis using PFI and WC in a large sample of youth from Guangzhou Health and Fitness Survey. We hypothesized that a high level of PFI may attenuate the association between body fat and the CVD risk factor profile.

Materials and methods

Subjects and design

This study was conducted as part of the baseline survey of a multi-center interventional project titled "A national school-based health lifestyle intervention among Chinese children and adolescents against obesity: rationale, design, and methodology of a randomized controlled trial in China." The study design and procedures have been described in detail elsewhere.[16] The present paper described a sub-sample of secondary school students aged 11–18years in grades 7–11. Students in the last year of secondary school (grades 9 and 12) were not contacted because of their study load. Children with missing information such as blood pressure (n=5), WC (n=17), or 50 m test (n=17) were excluded. Finally, a total of 1167 participants (588 males, 579 females) aged 11–18years agreed and completed the study, which included physical measurements, biochemical variable tests, and health-related physical fitness tests. The following ages were chosen to approximate developmental stages spanning childhood through adolescence: a) 11-12 (11.0-12.5): adolescent spurt in girls, transition for boys; b) 13–15 (13.0–15.5): late adolescence in girls, adolescent spurt in boys; and c) 16-18 (16.0-18.5): later adolescence in both genders.[13] This study was approved by the Ethical Committee of Peking University.

Ethics and consent to participate

This study was approved by the Ethical Committee of the Peking University. All participant students and their parents signed informed consents voluntarily.

Anthropometric characteristics

Height, weight, and WC were measured according to standardized methods by trained doctors, with the child wearing light clothing. Height was measured to the nearest 0.1 cm, and weight was measured to the nearest 0.1kg. BMI was defined as weight/height2 (kg/m^2).

CVD risk factors

Resting systolic and diastolic blood pressure (SBP and DBP, respectively) were measured in a seated position after at least 5min of rest and then again after 1min. The average of the two BP measurements was used in analyses. The mean arterial pressure (MAP) was calculated as DBP+ (0.333 (SBP-DBP)). After a 12h overnight fast, 5ml of venous blood samples was obtained from the antecubital vein and collected into ethylenediamineteraacetic acid vacuum tubes. Triglyceride (TG) and total cholesterol (TC) concentrations were measured by enzymatic methods. High-density and low-density lipoprotein (HDL and LDL, respectively) were measured via clearance method. Fasting glucose was measured by the glucose oxidase method. The ratio of TC: HDL was calculated.

CVD risk score

A CVD risk score was derived by first standardizing the individual CVD risk variables for age by regressing them onto age, age 2, and age 3 to account for any nonlinearity in age-related differences and then summing the age-standardized residuals (Z-scores) for SBP, DBP, TG, TC, HDL, LDL, and glucose. The age-standardized HDL was multiplied by−1 because it is inversely related to metabolic risk. The scores were continuous measures of metabolic risks, with higher scores showing a poorer profile. By definition, its mean is 0.

Health-Related fitness assessment

Cardio respiratory Fitness (CRF) The test was measured in minutes and seconds. Adequate warm-up exercise was advised before the test. When the investigator said, "take your marks," subjects in a group of six to eight stood behind the starting line; when the investigator said, "go," the subjects began the 800/1000m run/walk. The subjects were instructed to try to maintain a steady speed and finish the run as fast as they could. Walking was permitted if a subject could not keep running. All girls did the 800m run/walk, and boys did the 1000m run/walk. Lower scores indicate better performance.

Muscular strength (MS)

The standing long jump test assesses lower limb explosive strength. The child jumps as far as possible off the stand, trying to land with both feet together and maintaining the equilibrium once landed (the child was not allowed to put the hands on the floor). The score was obtained by measuring the distance between the last heel mark and the take-off line. Two attempts were allowed, and the best score was retained. Higher scores indicate better performance.

Speed-agility (SP-AG)

The 50m sprint test measures the maximum running speed of the child. This test was carried out along 50m delimited by six aligned marker cones, within a distance of 10m between every two neighboring cones. With 3m distance, six more marker cones were placed in parallel, marking the running track. The child was instructed to run as quickly as he/she could after the starting signal. Two tries were allowed, and the best score was retained. Lower scores indicate better performance.

PFI

PFI was derived from CRF, MS, and SP-AG. Each of these physical fitness variables was standardized to allow comparisons among the tests, for example, Z=([value–mean]/SD). CRF z-score and SP-AG z-score were inverted by multiplying by −1 so that a higher score corresponds to better performance.[17]

Statistical analyses

Children were categorized as low WC (normal WC) or high WC (high or normal high WC) using Chinese standard age-and gender-specific WC[18] values. Given that standardized cutoffs currently do not exist, the children were also classified into low or high PFI groups based on gender (i.e., the 25th percentile for PFI values). Cutoff points in the present study for boys and girls were −0.5980 and −1.7997, respectively. The approach seemed reasonable for health-related cutoff points, because among adults, a meta-analysis showed that the relative risk for CVD was higher among those who were below the 20th to 25th percentile of the fitness distribution compared with those in higher percentiles.[19] Children were grouped into the following groups based on their WC and PFI: Low-WC/High-PFI, Low-WC/Low-PFI, High-WC/High-PFI, and High-WC/Low-PFI. The differences in the characteristics between boys and girls were determined using t-test and Chi-square test, where appropriate. Differences across groups for individual CVD risk factor variables and CVD risk score were assessed by analysis of covariance, controlling for chronological age, within each gender. Post Hoc analyses were analyzed by the Bonferroni multiple comparison tests. Analyses were executed with the SPSS package (version21.0).

Result and discussion

As shown in Table 1, girls showed significantly lower height, weight, BMI, WC, SBP, DBP, MAP, HDL-C, glucose, PFI, and CVD risk scores than boys, but higher TC than boys ($p<0.05$). As shown in Table 2, in males, participants in the low-WC/low-PFI group had lower BP than those in the High-WC/High-PFI group ($p<0.05$). For both genders, the Low-WC group demonstrated lower BP values than the High-PFI group with the same PFI group ($p<0.05$). Similarly, lower TC, LDL, TC: HDL-C, and higher HDL were also found in the Low-WC groups than in the High-WC groups within the same PFI groups in males ($p<0.05$). In general, males and females in the High-PFI groups exhibited better blood lipids and glucose concentrations than those in the Low-PFI groups regardless of WC, although none of the differences reached statistical significance. Figure 1 showed the results for the CVD risk scores. In general, a significant trend was noted across WC-PFI groups in both genders ($F=23.23$, $p<0.001$ in males and $F=2.98$, $p<0.05$ in females). In males and females, the High-WC/Low-PFI group had the highest composite risk scores (2.415 and 0.603, respectively), which represented a poorer CVD risk profile. The Low-WC/High-PFI group had the lowest score (−0.386 and−0.906, respectively), which represented the best metabolic profile ($p<0.05$). Additionally, in contrast to the Low-WC group, males in the High-WC group showed higher scores within a fitness group ($p<0.05$). As shown, these scores were lower in females than in males. The main finding of the current study was the inverse relationships between clustering of CVD risk factors and body fat, which was in agreement with the findings of previous studies.[20,21] Specifically, we observed that an increased WC was associated with poorer CVD risk factor profile in boys and girls regardless of PFI. Longitudinal studies have shown that CVD risk factors track reasonably well from adolescence to adulthood,[22] and the first appearance of differences between adults with and without metabolic syndrome occurred at ages 6 and 13 for WC in boys and girls, respectively.[23] This result highlighted the importance of preventing CVD by controlling pediatric obesity at the very earliest stages of life.

A main objective of this study was to determine if a higher level of PFI would positively influence the CVD risk factor profile within WC groups. To the best of our knowledge, the present study may be the first to use PFI for exploring the combined effects of WC and fitness on the CVD risk factors in children and adolescents. Single fitness seems insufficiently comprehensive; however, PFI, as a composite score, may partially compensate for one-sidedness in single fitness. Our results showed an amelioration of the direct relationship between fat and CVD risk factors, although none of the relationships between PFI and CVD risk factors reached statistical significance. Specifically, high levels of PFI resulted in better blood lipids and CVD risk scores within WC categories, and the differences were more pronounced among the high WC group. Clinical cutoff points based on PFI are not available so the quartile split was attempted to use in the present paper. The splitting approach seemed reasonable, because a meta-analysis showed that the relative risk for CVD was higher among adults who were below the 20th to 25th percentile of the fitness distribution compared with those in higher percentiles.[19] However, the inability to show significant differences between Low-PFI and High-PFI may be also due to the use of quartile split to categorize groups. Considering that youth are the most physically fit segment of the population, healthy subjects in our study might have been categorized into the low fitness group; thus, bias toward the null may occur because of misclassification.[24] Analyses based on extreme values would allow for more discriminating power to detect group-level differences. For example, a fitness level below 5th is associated with CVD among children and adolescents.[25,26] Furthermore, the dependent variable in our analysis relied on levels of precursor risk factors for CVD, so significant differences may not exist in children between low PFI and high PFI within WC categories because of the extremely low incidence of acute coronary events. In addition, the majority of students may have mediocre scores in PFI, which could explain why the significant effects of PFI on CVD risk factors were lacking. Some researchers also suggested that such results may be partly influenced by the more objective nature of the anthropometry test compared with the health-related fitness test employed in the present study.[8] Although none of the differences reached statistical significance, the link was still important in health term.

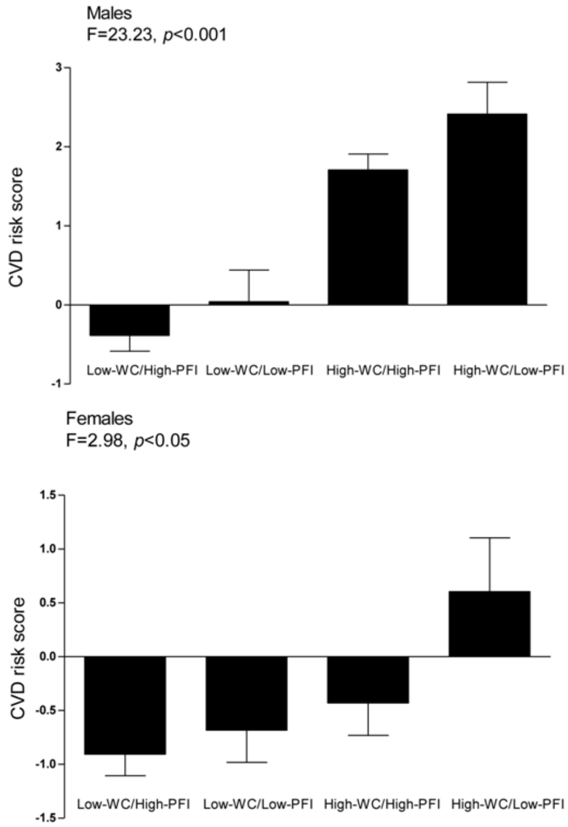

Figure 1 The CVD risk score among 11-18years adolescents in Guangzhou.

Our data showed some gender differences such that the CVD risk factors varied among groups between boys and girls. The significant differences across WC-PFI groups were more common among males than those among females. For example, all blood lipids were significantly different across the four groups in boys, but only TG and HDL-C were found in girls. This finding was in agreement with previous studies in adolescents.[10,11] Furthermore, High-WC boys had poorer blood lipids than those in Low-WC group within the same PFI, whereas the differences in girls were insignificant. The reasons for these specific gender differences remain unclear. Genetic predisposition and several other environmental and biological factors might be involved in the interplay among fitness, fatness, and CVD risk factors in different genders.[24]

Recently, there has been increased interest in the genesis of the features of the metabolic syndrome in children and adolescence.[27] Because there was no clear definition of the metabolic syndrome in children or adolescence, we used a composite score of the risk factors related to the metabolic syndrome. Results from the present study clearly demonstrated that CVD risk scores varied by fitness-fatness categories. Our results showed that boys and girls with High-WC/Low-PFI had the higher CVD risk scores than their counterparts in Low-WC/High-PFI group, which was concordant with previous researches.[10,28] Although not significant, a similar tendency in CVD scores was found between participants in High-PFI groups and Low-PFI groups within fatness categories. The beneficial effect of fitness on the relationship between fatness and CVD risk factors has been demonstrated in previous studies in youth[10,29] and adults.[30] This finding suggested high levels of fitness regardless of WC level have favorable impact on cardiovascular health across life span. In keeping with previous studies in children and adolescents, the effects of fitness on CVD risk profile were strongly confounded by WC, whereas the more robust relationships found between fatness and CVD risk scores proved to be independent of fitness when investigated the joint association of fitness and fatness on CVD risk factors.[29] This implied that fatness may have a stronger association with CVD risk factors than fitness in this age group. Evidence from our study and others had important implications for the amelioration the CVD risk factors by reducing obesity and promoting a physically active lifestyle in fat youth.

The findings of this study must be interpreted in light of its limitations. The cross-sectional study design limits drawing causal inferences, and prospective studies on this topic are needed. In addition, no validation and reliability tests were conducted to assess the quality of anthropometry and fitness measurements; clinical cutoff points for PFI have not yet been developed for the youth population. Thus, additional work among evidence-based cutoff points for PFI should aim to provide and utilize such cutoff points in a similar analysis as conducted in the present study. We were also unable to adjust for biological maturity status because no measure was available. Although we accounted for age-related changes in the variables, these variables are influenced by the dynamic nature of puberty.[31] For example, HDL-C declines during puberty, whereas body fatness, TG, and blood pressure increase.[9] Therefore, biological maturity status presents a major confounding variable that we were unable to account for in this study.[32]

Table 1 Characteristics of the study subjects according to gender among 11-18years adolescents in Guangzhou

	Males (n=588)	Females (n=579)	Total (n=1167)
Age, year	14.3 (1.8)	13.9 (1.7)***	14.1 (1.7)
Height, cm	167.1 (0.1)	159.0 (0.1)***	163.1 (0.1)
Weight, kg	56.5 (12.7)	49.1 (8.6)***	52.8 (11.5)
BMI, kg/m^2	20.1 (3.8)	19.4 (3.2)***	19.8 (3.5)
WC, cm	71.7 (9.6)	69.1 (7.3)***	70.4 (8.6)
Normal high or high WC, n (%)	239 (40.0)	180 (30.5)*	419 (35.3)
SBP, mm Hg	101.9 (9.7)	95.1 (7.5)***	98.5 (9.3)
DBP, mm Hg	64.3 (6.9)	61.2 (6.2)***	62.8 (6.7)
MAP, mm Hg	76.8 (7.1)	72.5 (6.0)***	74.7 (6.9)
TG, mmol/l	1.0 (0.5)	1.0 (0.5)	1.0 (0.5)
TC, mmol/L	4.0 (0.8)	4.1 (0.9)*	4.0 (0.9)
HDL, mmol/l	1.2 (0.3)	1.3 (0.3)*	1.3 (0.3)
LDL, mmol/l	2.1 (0.6)	2.2 (0.7)	2.2 (0.6)
Glucose, mmol/l	4.6 (0.6)	4.5 (0.6)*	4.6 (0.6)
PFI	0.820 (2.4)	-0.815(1.8)***	0.007 (2.2)
CVD risk score	0.586 (3.4)	-0.587(3.4)***	0.001 (3.4)

BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; MAP, mean arterial pressure; TG, triglyceride; TC, total cholesterol; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; PFI, general physical fitness index
Values are number (percentage) or mean (SD).
*p<0.05, ***p<0.001 for boys vs. girls

Table 2 Differences in cardiovascular disease risk factors across WC and general fitness groups among adolescents 11-18yrs in the Guangzhou study population

	Males (n = 588)						Females (n = 579)					
	Low-WC		High-WC				Low-WC		High-WC			
	High-PFI	Low-PFI	High-PFI	Low-PFI			High-PFI	Low-PFI	High-PFI	Low-PFI		
Variable	(n = 269)	(n = 81)	(n =173)	(n = 65)	F	p	(n = 308)	(n = 95)	(n = 127)	(n = 49)	F	p
SBP, mm Hg	99.9 (0.6)‡†	99.3 (1.0)*§	105.7 (0.7)	104.0 (1.1)	17.8	<0.001	94.4 (0.4)‡	93.9 (0.8)*	96.1 (0.7)	98.2 (1.0)	5.85	<0.05
DBP, mm Hg	63.5 (0.4)†	62.6 (0.7)*§	66.0 (0.5)	65.9 (0.8)	8.28	<0.001	60.5 (0.4)‡†	60.9 (0.6)	62.3 (0.6)	63.3 (0.9)	4.53	<0.05
MAP, mm Hg	75.7 (0.4)‡†	74.8 (0.8)*§	79.2 (0.5)	78.6 (0.8)	14.17	<0.001	71.8 (0.3) ‡†	71.8 (0.6)*	73.6 (0.5)	75.0 (0.9)	5.81	<0.05
TG, mmol/l	0.9 (0.1)‡	1.0 (0.1)	1.0 (0.1)	1.2 (0.1)	7.11	<0.001	0.9 (0.1)	1.0 (0.1)	1.0 (0.1)	1.1 (0.1)	3.46	<0.05
TC, mmol/L	3.8 (0.1)‡†	3.9 (0.1)	4.1 (0.1)	4.2 (0.1)	5.47	0.001	4.1 (0.1)	4.3 (0.1)	4.0 (0.1)	4.0 (0.1)	1.1	NS
HDL-C, mmol/l	1.3 (0.1)‡	1.3 (0.1)*	1.2 (0.1)	1.1 (0.1)	6.6	<0.001	1.3 (0.1)	1.3 (0.1)	1.3 (0.1)	1.2 (0.1)	2.97	<0.05
LDL-C, mmol/l	2.0 (0.1)‡†	2.2 (0.1)	2.2 (0.1)	2.3 (0.1)	6.3	<0.001	2.2 (0.1)	2.2 (0.1)	2.2 (0.1)	2.2 (0.1)	0.07	NS
Glucose, mmol/l	4.6 (0.1)	4.7 (0.1)	4.6 (0.1)	4.7 (0.1)	1.76	NS	4.6 (0.1)	4.5 (0.1)	4.5 (0.1)	4.5 (0.1)	0.92	NS
TC:HDL-C	3.1 (0.1) †	3.2 (0.1)*	3.5 (0.1)	4.0 (0.1)	15.62	<0.001	3.2 (0.1)	3.3 (0.1)	3.3 (0.1)	3.5 (0.2)	1.49	NS
CVD risk score	−0.386(0.2)‡†	0.039 (0.4)*§	1.708 (0.2)	2.415 (0.4)	23.23	<0.001	−0.906 (0.2)‡	−0.682 (0.3)	−0.431 (0.3)	0.603 (0.5)	2.98	<0.05

Values are mean (SE)

*Low-WC/Low-PFI significantly different from High-WC/Low-PFI; †Low-WC/High-PFI significantly different from High-WC/High-PFI; ‡Low-WC/High-PFI significantly different from High-WC/Low-PFI; §Low-WC/Low-PFI significantly different from High-WC/High-PFI; ||High-WC/Low-PFI significantly different from High-WC/High-PFI; ¶Low-WC/Low-PFI significantly different from Low-WC/High-PFI; NS, non significant.

Conclusion

In summary, the results showed a negative influence of WC on CVD risk factors in children adolescents in Guangzhou, China. They also provided some evidence for the potential positive effect of health-related physical fitness on the prevention of CVD risk factors.

Acknowledgements

All the authors have made substantial contributions to the study. ZG: conception and design of the study, acquisition of data, analysis and interpretation of data; drafting the article; final approval of the version to be submitted; FS: acquisition of data, analysis and interpretation of data; revising the manuscript critically for important intellectual content; final approval of the version to be submitted; YZ: interpretation of data; revising the manuscript critically for important intellectual content; final approval of the version to be submitted; JJ: conception and design of the study; revising the manuscript critically for important intellectual content; final approval of the version to be submitted; YC: conception and design of the study; acquisition of data, analysis and interpretation of data; drafting the article; final approval of the version to be submitted. All authors were involved in writing the paper and had final approval of the submitted and published versions. This work was supported by the Guangdong Science and Technology Program (No. 2014A020220002); the Guangdong Natural Science Fund (No. 2015A030313093); and the Special Fund for Scientific Research in the National Health and Family Planning Commission of the People's Republic Of China (No. 201202010).

Conflict of interest

The author declares no conflict of interest.

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