Body Shape Index and Body Roundness Index: Two New Body Indices for Prediction of Multiple Metabolic Risk Factors in Southern China Adults

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Abstract: This purpose was to compare the ability of body shape index (ABSI) and body roundness index (BRI) with waist circumference (WC), body mass index (BMI), waist-to-hip ratio (WHR), waist-to-height ratio (WHtR) and body adiposity index (BAI) to predict metabolic risk.
The cross-sectional study was conducted in 17,360 Chinese subjects (were aged 18-95 years old) who escaped cardiovascular disease (CVD) or diabetes. Biochemical and anthropometric variables were measured by trained staff. Receiver operating characteristic curve (ROC) and optimal cutoff values of obesity indices were recruited to compare the predictive ability for metabolic risk factors. The mean age of subjects was 53.7(13.1) years, 41.6 % were males. Within young group (<60 years), the areas under the curve (AUC) demonstrated that WC, BMI, WHR, WHtR and BRI were able to similarly predict high metabolic risk in males (0.74 vs. 0.74 vs. 0.73 vs. 0.73 vs. 0.73) and in females (0.73 vs. 0.73 vs. 0.71 vs. 0.73 vs. 0.73), while the approximate predictive ability were only acquired in males (0.73 vs. 0.73 vs. 0.70 vs. 0.73 vs. 0.73) within elder group (≥60 years). The optimal cut-off values of BRI for high metabolic risk were calculated in males (<60 y: 3.49 vs. ≥60 y: 3.46) and females (<60 y: 3.47 vs. ≥60 y: 3.60). Meanwhile, BRI displayed a strong prediction to elevated BP and elevated TG in males (AUC = 0.64; AUC = 0.70) and to elevated BP, elevated TG and elevated SUA in females (AUC = 0.67; AUC = 0.69; AUC =0.70). BRI was able to similarly predict high metabolic risk compared to WC, BMI, WHR, WHtR and BAI, while ABSI was not. Moreover, BRI revealed specific predictive ability for elevated BP, elevated TG and elevated SUA.

Keywords: A body shape index; Body roundness index; Metabolic risk factors; Southern China adults

1. Introduction

Metabolic syndrome (MetS) consist of a group of metabolic risk factors, which plays a vital role in development of atherosclerotic heart disease, diabetes mellitus and cancer[1-3]. So far, over 33.9% of elderly Chinese reached abnormal metabolism and caused a large disease-related healthcare burden[4]. According to the International Diabetes Federation (IDF) in 2009, the general diagnosis criteria of metabolic syndrome consisted with obesity, elevated blood pressure (BP), elevated fasting plasma glucose (FPG), elevated triglyceride (TG) and reduced high-density lipoprotein cholesterol (HDL-C)[5].

Obesity played an important role in the development of cardiometabolic disorder[6]. The prevalence of obesity among adults was increasing rapidly worldwide; a similar rapid increase had reached epidemic levels in China, which poses heavy public health and economic burdens[7]. Obesity was mainly due to the disproportionate growth of adipose tissue and lean body mass which can lead to further morbidity and mortality from cardiovascular disease[8, 9]. The obesity was the most commonly used measure to assess the risk involved with adiposity-related metabolic derangements, whereas the use of more accurate methods such as dual-energy X-ray absorptiometry (DXA), hydrostatic weighing, bioelectrical impedance or even skinfold thickness were limited due to its complexity and/or cost[10-12]. More epidemiological studies have shown the anthropometric measures were accepted for the evaluation of obesity for their simplicity and usefulness[13-15]. The body mass index (BMI) has been long used as a diagnostic index of general obesity and could reflect the overall distribution of body fat[16]. Moreover, waist circumference (WC), body adiposity index (BAI), waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) have been used to predict metabolic risk factors in numerous studies[17-20]. However, people have gradually found that traditional anthropometric indices failed to discriminate fat and muscle mass[21]. So, the controversy raised over which anthropometric parameter can best define obesity and predict metabolic risk[22]. Hence, researchers have explored new anthropometric indices in an attempt to improve above limitations[23]. Fortunately, previous study found that two new anthropometric indices named body shape index (ABSI) and body roundness index (BRI) were more associated with cardiovascular disease and mortality hazards than BMI and WC[24-26].

In this study, we conducted a population-based cross-sectional study to assess the ability of obesity indices for predicting multiple non-adipose metabolic risk factors in Chinese subjects. To further evaluate the importance of obesity factor in Chinese elderly people, we adopted seven anthropometric indices as well as more comprehensive metabolic risk factors, including elevated BP, elevated FPG, elevated TG, reduced HDL-C and elevated serum uric acid (SUA), in the present study.

2. Material and methods

2.1. Study population

The cross-sectional data was extracted from the baseline records of Zhejiang Metabolic Syndrome Cohort initiated in Zhejiang Province from 2009 to 2012. A total of 22,649 participants (9,527 males and 13,122 females, mean age was 54.86±14.2 years) were recruited. Exclusion criteria: (1) severe infective diseases and malignancies in baseline; (2) patients with T2DM, CVD

and Stroke in baseline; (3) less than 18 years old; (4) without biochemical and anthropometric data. A total of 17,360 (7,226 males and 10,134 females) participants met these criteria were finally included in this study. Additionally, inclusion criteria and selection flowchart for all samples shown in Figure 1. This study was approved by the Human Research Ethics Committee of the Zhejiang University, Zhejiang, China. All participants provided written informed consent before participation.

2.2. Measurements

Height (cm), body weight (kg), waist circumference (WC; cm), hip circumference (HC; cm), systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured by trained assistants using same equipment. Height and weight were measured with the subjects wearing light clothing and no shoes. Height was recorded to the nearest 0.1 cm and body weight to the nearest 0.1kg. Body mass index (BMI) was computed as weight (kg) divided by height squared (m^2). Girth of the midpoint between the lowest point of the rib and the upper edge of the iliac crest were calculated as waist circumference (WC). The length of the horizontal position of the hip protrusion was calculated as the hip circumference (HC) [14]. The measurements of WC and HC were taken to the nearest 0.1 cm. Waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) were respectively calculated as WC divided by HC and WC divided by height. BAI was calculated as HC (cm)/height$^{1.5}$ (m) minus 18[27]. ABSI was calculated using formula as $\mathrm{ABSI} = \frac{\mathrm{WC}}{\mathrm{BMI}^{2/3}\mathrm{Height}^{1/2}}$ and BRI was calculated using formula as $\mathrm{BRI} = 364.2 - 365.5 \times \sqrt{1 - (\frac{(\mathrm{WC}/(2\pi))^2}{(0.5\mathrm{Height})^2})}$. Sitting blood pressure was measured 2 times after at least 20 minutes of rest using the standardized desktop sphygmomanometer. The average blood pressure derived from two measurement readings was used[26, 28].

After an overnight fast of at least 12 hours, blood samples of each participant were collected by venipuncture. EDTA blood was collected in pre-cooled tubes on ice, centrifuged at 4000 rpm for 15 min at 4℃. EDTA plasma and serum aliquots were stored at −80℃ until use. Fasting plasma glucose (FPG) was measured by the hexokinase method, SUA and lipid profile containing total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C) and low-density lipoprotein cholesterol (LDL-C) were measured by the enzymatic method using an Abbott Aeroset autoanalyzer.

2.3. Criteria for multiple metabolic risk factors

According to the diagnosis criteria of MetS by International Diabetes Federation (IDF) in 2009[5], the comprehensive non-adipose metabolic risk factors included the following items: (1) elevated BP: systolic blood pressure (SBP) (≥ 130 mmHg) or diastolic blood pressure (DBP) (≥ 85 mm Hg), or ongoing antihypertensive medications; (2) elevated FPG: FPG≥ 5.6 mmol/L and/or diagnosis of type 2 diabetes, or ongoing anti-diabetic treatment; (3) elevated TG: TG≥ 1.7 mmol/L; (4) reduced HDL-C: HDL-C < 1.03 mmol/L in men and HDL-C < 1.29 mmol/L in women. In addition, we also enrolled: (5) elevated SUA: SUA > 420 μ mol/L according to the diagnosis criteria of hyperuricemia in 2000[29]. The people with three or more risks were diagnosed as “high metabolic risk population” in present study.

2.4. Statistics

The continuous variables were presented as means and standard deviations (SD), categorical variables as counts or percentages. The one-way analysis of variance and the chi-squared test were used to compare the baseline characteristics of participants stratified by number of risk factors. To determine the optimal cut-off values and compare the ability of the obesity indices for predicting multiple metabolic risk factors, the ROC and AUC were obtained using MedCalc v18.2.1 software and optimal cut-off values were identified from the maximum Youden index (sensitivity plus specificity-1). The Hanley & McNeil method was used to compare the inter-group differences of AUC. Another analysis was performed by SPSS 22.0 software. All analyses were two-sided, and the difference was statistically significant at $P < 0.05$.

3. Results

3.1. Basic characteristics of the objects

As shown in Table 1, according to the number of metabolic risk factors, subjects were divided into non-metabolic risk factor group, low metabolic risk factor group (<3) and high metabolic risk factor group (≥3), and the differences of basic characteristics among three groups were analyzed. The average age of subjects with high metabolic risk factors was 59.66 (12.57) years old, while the people without metabolic risk factors was 48.44 (14.88) years old, and the difference was significant ($p < 0.001$). In addition, gender and multiple anthropometric parameters such as BMI, WC, HC, WHR, WHtR, BAI, ABSI and BRI were significant differences among three groups ($p < 0.001$). Meanwhile, the mean value of anthropometric parameters was increased with the number of metabolic risk factors. Moreover, the mean levels of SBP, DBP, FPG, TG, HDL-C, LDL-C, and SUA increased with the number of metabolic risk factors, and revealed significant difference among multiple groups ($p < 0.001$). In addition, the average values of SBP, FPG and TG reached abnormal levels in high metabolic risk factor group, which were 146.58 (19.23), 5.58 (1.52) and 2.91 (2.04), respectively.

3.2. Metabolic risk factors and anthropometric parameters

Table 2 shows the relationship between the number of metabolic risk factors and the anthropometric index. Whether in men or women, the average level of WC, BMI, WHR, WHtR, BAI, ABSI and BRI increased with the number of metabolic risk factors. Moreover, BRI in the group with high metabolic risk increased significantly when compared with the group without metabolic risk factors, and the values in males were 4.23 (1.26) vs. 2.73 (0.84), in females were 4.97 (1.33) vs. 2.89 (1.01). As shown in Table 2, 2650 subjects (1088 men and 1562 women) had high metabolic risk factors (≥3).

3.3. AUC of anthropometric indices for metabolic risk factors

Table 3 shows the result of receiver operating characteristic curve (ROC) in different gender, and revealed the area under the curve (AUC) for each obesity index to predict multiple metabolic risk factors. Among men, WC, BMI, WHR, WHtR, BAI, and BRI had better predictive ability for

high TG than other metabolic risk factors, and their AUCs were 0.703, 0.702, 0.675, 0.695, 0.621 and 0.695, moreover, they also were predictive for high BP, with AUCs of 0.620, 0.621, 0.626, 0.638, 0.605 and 0.638, respectively. Similarly, WC, BMI, WHR, WHtR, BAI, ABSI, and BRI displayed a best predictive ability to high SUA, with AUCs of 0.691, 0.684, 0.656, 0.702, 0.659, 0.604 and 0.702, respectively. The predictive ability of high TG still exists, and their AUCs were 0.692, 0.679, 0.670, 0.693, 0.626, 0.607 and 0.693, respectively. In addition, the AUCs of obesity parameters for predicting metabolic risk factors were significant (figure 2).

Table 4 shows that WC, BMI, WHR, and WHtR revealed similar abilities to predict high metabolic risk. In the young group (<60 years), the AUCs for men were 0.739, 0.737, 0.725, 0.732, for women were 0.732, 0.727, 0.712 and 0.732. However, in the elderly group (≥60 years), WC, BMI, WHR, and WHtR were significant in predicting high metabolic risk only for men, and AUCs were 0.728, 0.726, 0.703, and 0.726, respectively. At the same time, whether in the males or females, BRI were strong for predicting high metabolic risk. The AUC in men was (<60 years: 0.732 vs. ≥60 years: 0.726), and in women was (<60 years: 0.732 vs. ≥60 years old: 0.677). In addition, the best cut-off value predicted by BRI was (<60 years: 3.49 vs. ≥60 years: 3.46) in men and (<60 years: 3.47 vs. ≥60 years: 3.60) in women. Meanwhile, the sensitivity, specificity and Youden index of these obesity-related anthropometric measurements that predicted high metabolic risk factors were also shown in table 4. In addition, the differences of predictive ability for high metabolic risk factors by anthropometric index were significant ($p<0.001$) (figure 3).

4. Discussion

In this cross-sectional study, we compared two new anthropometric indices (ABSI and BRI) with WC, BMI, WHR, WHtR and BRI for their ability to predict multiple metabolic risk factors in southeast China. The results indicated that WC, BMI, WHR, WHtR and BRI were able to similarly predict high metabolic risk and their predictive abilities were more accurate than BAI and ABSI. Moreover, BRI revealed specific predictive ability for elevated BP, elevated TG and elevated SUA.

Body weight began to attract intense interest when it linked with the development of health and disease[18]. Obesity is mainly due to the disproportionate growth of adipose tissue and lean body mass. Abdominal obesity played a vital role in MetS and was closely associated with various metabolic risk factors[30]. Moreover, the visceral fat (including abdominal, mediastinal and epicardial adipose tissue) could produce a lot of compounds that have autocrine, paracrine and endocrine activities, which could influence the metabolism and cardiovascular system[31, 32]. To the best of our knowledge, metabolic risk factors can not only promote the development of cardiovascular diseases, it may also be related to the mortality and incidence of multiple tumors[33, 34]. Obesity-related indicators are simple, practical, and non-invasive for predicting body fat mass and distribution[35]. In addition to the traditional WC, BMI, WHR, WHtR and BAI measurements, two new indices ABSI, BRI can effectively discriminate fat and muscle mass[26, 36]. Diego MU et al[34]. found that the traditional adiposity measures were better predictor to all-cause and CVD mortality risk, the association of BAI with CVD risk factors was relatively stronger than for BMI, waist circumference. Meanwhile, the previous results demonstrated that BRI, not ABSI was superior measure compared to BMI, WC and WHtR for determining the presence of left ventricular hypertrophy (LVH), especially for eccentric LVH[24].

In our study, the contents of metabolic risk factors mainly included elevated blood pressure (BP), elevated fasting plasma glucose (FPG), elevated triglyceride (TG), reduced high-density

lipoprotein cholesterol (HDL-C), elevated serum uric acid (SUA). The ability for predicting metabolic risk was compared among multiple anthropometric indices. The results revealed a significant prediction by obesity-related indices, while the new index of BRI demonstrated excellent prediction for high metabolic risk. However, it was notable that the prediction of anthropometric indicators for high metabolic risk was more obvious in younger group but not in elder group. The findings suggested that BRI was able to similarly predict high metabolic risk compared to WC, BMI, WHR and WHtR, while ABSI was not. The previous community-based cross-sectional study was conducted with 5,685 elderly Chinese subjects (⩾60 years)[25]. They recruited ROC analyses to compare the predictive ability as well as determine the optimal cutoff values of the obesity indices for multiple metabolic risk factors. According to the areas under the curve (AUC), BMI, WC and WHtR were able to similarly predict high metabolic risk in males (0.698 vs. 0.691 vs. 0.688), while in females, BMI and WC were able to similarly predict high metabolic risk (0.676 vs. 0.669). In addition, they found BMI, WC and WHtR to be more accurate than WHR and BAI for predicting multiple metabolic risk factors, meanwhile BMI, WC and WHtR were able to similarly predict the high metabolic risk population in males, while WHtR was not in females. There were several obvious contradictions between these results and ours. First of all, the results of us shown that the obesity-related indicators in the young group were more significant in predicting the high metabolic risk, but in the elderly population the predictive ability was obviously insufficient. Moreover, the area under the curve (AUC) of anthropometric indices to metabolic risk was more meaningful and valuable. There were, however, several limitations of their study. The subjects in this study were all Chinese elderly and were from single area of Shanghai that may trigger sample selection bias. Secondly, this study only enrolled subjects who had completed the comprehensive health check study, which may bias the primary findings. In addition, insufficient sample size may also cause the predictive effect to be failed.

Fortunately, our research included a large sample size that involved multi-regional, multi-aged population, which avoided the shortcomings of many previous studies[24, 25, 37, 38]. In addition, the study was not only conducted in different gender, the population was divided into young and elder groups at the critical value of 60 years old, which effectively avoided the defects of single sample and insufficient representativeness. Meanwhile, two new obesity-related indexes ABSI and BRI were also included in the comparison of prediction except the traditional WC, BMI, WHR, WHtR and BAI. The limitations in the present study should be mentioned. The ABSI was initially developed to predict mortality hazard in a prospective study, and we recruited it to predict metabolic risk in a cross-sectional study, which may be the main reason why the ABSI failed to display superior predictive power. In addition, the two new anthropometric indices were first developed in Western countries and America, and should be modified to make them suitable for Chinese populations. Second, the study was conducted with rural populations residing in southeast China, the unique lifestyle may have influenced the body shape and metabolic indices. Third, although BRI improved quantification of body shape and provided a more accurate estimate of total %body fat and %visceral adipose tissue (VAT), the calculation of BRI was so complicated that it sacrificed simplicity in comparison to BMI which may influence the clinical application. The longitudinal relationship between the two new anthropometric indices and metabolic risk should be examined in future, meanwhile the multi centers and a larger sample size are needed to identify the association of obesity indices with more comprehensive metabolic risk factors.

In conclusion, the present study indicated that BRI, not ABSI was a superior measure compared

to WC, BMI, WHR, WHtR and BAI for determining the presence of metabolic risk, especially for high metabolic risk. In addition, BRI induced the strong predictive ability for males with elevated TG and females with elevated SUA.

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Abbreviations: MetS: metabolic syndrome; WC: waist circumference; HC: waist circumference; BMI: body mass index; WHR: waist-to-height ratio; WHtR: waist-to-hip ratio; BAI: body adiposity index; ABSI: a body shape index; BRI: body roundness index; SBP: systolic blood pressure; DBP: diastolic blood pressure; FPG: fasting plasma glucose; TG: triglyceride; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; SUA: serum uric acid; BP: blood pressure.

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Table 1 Baseline characteristics of study subjects

Variables	N	Number of components in MetS			*p* value
		None	<3	≥3	
Gender					<0.001
Male	7226	1785 (38.3%)	4308 (43.3%)	1133 (41.3%)	
Female	10134	2876 (61.7%)	5650 (56.7%)	1608 (58.7)	
Age (years)	17290	48.44 (14.9)	56.63 (14.1)	59.66 (12.6)	<0.001
Height (cm)	17057	160.69 (7.9)	160.05 (8.3)	159.8 (8.6)	<0.001
Weight (kg)	16995	55.91 (8.7)	59.48 (10.3)	64.2 (10.8)	<0.001
WC (cm)	17018	75.11 (8.4)	80.27 (9.2)	85.8 (8.6)	<0.001
HC (cm)	17022	90.13 (6.1)	92.11 (6.7)	94.72 (6.7)	<0.001
BMI (kg/m2)	16967	21.62 (2.8)	23.15 (3.2)	25.06 (3.1)	<0.001
WHR	17004	0.83 (0.07)	0.87 (0.07)	0.91 (0.06)	<0.001
WHtR	16961	0.47 (0.05)	0.5 (0.06)	0.54 (0.05)	<0.001
BAI	16965	26.4 (3.9)	27.65 (4.2)	29.07 (4.3)	<0.001
ABSI	16878	0.08 (0.005)	0.08 (0.005)	0.08 (0.005)	<0.001
BRI	16961	2.83 (0.9)	3.47 (1.1)	4.15 (1.1)	<0.001
SBP (mmHg)	17359	112.52 (10.2)	133.94 (21.2)	146.58 (19.2)	<0.001
DBP (mmHg)	17359	68.97 (7.9)	79.01 (11.7)	84.64 (11.1)	<0.001
FPG (mmol/L)	17360	4.6 (0.5)	4.93 (1.0)	5.58 (1.5)	<0.001
TG (mmol/L)	17360	0.97 (0.3)	1.52 (1.0)	2.91 (2.0)	<0.001
HDL–C(mmol/L)	17360	1.62 (0.3)	1.5 (4.4)	1.16 (0.3)	<0.001
LDL–C(mmol/L)	17344	2.52 (0.7)	2.76 (0.8)	2.88 (0.8)	<0.001
SUA (μmol/L)	17360	280.96 (65.6)	315.93 (87.9)	377.27 (109.3)	<0.001
Elevated BP	8578	0	6076 (61.0%)	2502 (91.3%)	<0.001
Elevated FPG	2574	0	1374 (13.8%)	1200 (43.8%)	<0.001
Elevated TG	5134	0	2793 (28.0%)	2341 (85.4%)	<0.001
Reduced HDL-C	4506	0	2651 (26.6%)	1855 (67.7%)	<0.001
Elevated SUA	2222	0	1196 (12.0%)	1026 (37.4%)	<0.001

Data are expressed as mean ± standard deviation or counts (percentages). MetS: metabolic syndrome; WC: waist circumference; HC: waist circumference; BMI: body mass index; WHR: waist-to-height ratio; WHtR: waist-to-hip ratio; BAI: body adiposity index; ABSI: a body shape index; BRI: body roundness index; SBP: systolic blood pressure; DBP: diastolic blood pressure; FPG: fasting plasma glucose; TG: triglyceride; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; SUA: serum uric acid; BP: blood pressure.

Table 2 Number of metabolic risk factors and anthropometric indices

	Number of components in MetS						
	0	1	2	3	4	5	≥3
Male	1742	2400	1690	810	250	28	1088
WC	77.17 ± 7.9	80.52 ± 8.5	83.73 ± 8.9	87.45 ± 8.5	89.15 ± 7.4	89.25 ± 8.8	87.89 ± 8.3
BMI	21.59 ± 2.6	22.71 ± 2.9	23.87 ± 3.1	25.08 ± 3.1	25.6 ± 2.8	26.68 ± 3.3	25.25 ± 3.1
WHR	0.85 ± 0.06	0.88 ± 0.06	0.9 ± 0.06	0.92 ± 0.06	0.93 ± 0.05	0.94 ± 0.05	0.92 ± 0.05
WHtR	0.46 ± 0.05	0.48 ± 0.05	0.5 ± 0.05	0.52 ± 0.05	0.54 ± 0.05	0.54 ± 0.06	0.53 ± 0.05
BAI	23.98 ± 3.1	24.89 ± 3.3	25.72 ± 3.2	26.28 ± 3.2	26.75 ± 3.5	26.98 ± 5.4	26.4 ± 3.4
ABSI	0.0772 ± 0.005	0.0781 ± 0.005	0.0785 ± 0.005	0.0792 ± 0.004	0.0798 ± 0.004	0.078 ± 0.006	0.0793 ± 0.004
BRI	2.733 ± 0.9	3.128 ± 0.9	3.49 ± 0.9	3.872 ± 0.9	4.097 ± 0.9	4.232 ± 1.3	3.9341 ± 1.0
Female	2848	3216	2282	1228	306	28	1562
WC	73.81 ± 8.4	77.68 ± 9.1	81.14 ± 9.1	83.91 ± 8.4	86.29 ± 8.3	88.69 ± 7.2	84.46 ± 8.5
BMI	21.67 ± 2.9	22.75 ± 3.1	23.87 ± 3.3	24.79 ± 3.1	25.73 ± 3.3	26.04 ± 2.9	24.99 ± 3.1
WHR	0.82 ± 0.07	0.85 ± 0.07	0.87 ± 0.07	0.89 ± 0.07	0.9 ± 0.06	0.92 ± 0.06	0.9 ± 0.07
WHtR	0.47 ± 0.06	0.5 ± 0.06	0.52 ± 0.06	0.54 ± 0.06	0.56 ± 0.06	0.58 ± 0.06	0.54 ± 0.06
BAI	27.92 ± 3.7	29.08 ± 3.7	30.03 ± 3.9	30.67 ± 3.8	31.6 ± 3.9	32.31 ± 4.8	30.88 ± 3.8
ABSI	0.076 ± 0.006	0.0778 ± 0.006	0.0787 ± 0.006	0.0794 ± 0.005	0.0798 ± 0.005	0.0814 ± 0.005	0.0795 ± 0.005
BRI	2.892 ± 1.0	3.419 ± 1.1	3.863 ± 1.2	4.221 ± 1.1	4.552 ± 1.2	4.973 ± 1.3	4.2996 ± 1.2

Data are expressed as mean ± standard deviation. MetS: metabolic syndrome; WC: waist circumference; BMI: body mass index; WHR: waist-to-height ratio; WHtR: waist-to-hip ratio; BAI: body adiposity index; ABSI: a body shape index; BRI: body roundness index.

Table 3 Area under curves (95% CI) of anthropometric indices for metabolic risk factors

	WC	BMI	WHR	WHtR	BAI	ABSI	BRI
Male							
Elevated BP	0.62 (0.61-0.63) **	0.62 (0.61-0.63) **	0.63 (0.61-0.64) **	0.64 (0.63-0.65) **	0.61 (0.59-0.62) **	0.58 (0.56-0.59) **	0.64 (0.63-0.65) **
Elevated FPG	0.61 (0.59-0.62) **	0.62 (0.6-0.64) **	0.60 (0.58-0.61) **	0.61 (0.60-0.63) **	0.59 (0.57-0.61) **	0.53 (0.51-0.55) **	0.61 (0.6-0.63) **
Elevated TG	0.70 (0.69-0.72) **	0.70 (0.69-0.72) **	0.68 (0.66-0.69) **	0.70 (0.68-0.71) **	0.62 (0.61-0.64) **	0.58 (0.57-0.6) **	0.70 (0.68-0.71) **
Reduced HDL-C	0.64 (0.62-0.66) **	0.64 (0.63-0.66) **	0.62 (0.61-0.64) **	0.63 (0.61-0.65) **	0.57 (0.55-0.58) **	0.54 (0.52-0.56) **	0.63 (0.61-0.65) **
Elevated SUA	0.62 (0.60-0.63) **	0.62 (0.61-0.64) **	0.61 (0.59-0.62) **	0.61 (0.60-0.63) **	0.56 (0.55-0.58) **	0.54 (0.52-0.55) **	0.61 (0.6-0.63) **
Female							
Elevated BP	0.65 (0.64-0.66) **	0.63 (0.62-0.64) **	0.66 (0.65-0.67) **	0.67 (0.66-0.68) **	0.63 (0.62-0.64) **	0.62 (0.61-0.63) **	0.67 (0.66-0.68) **
Elevated FPG	0.61 (0.60-0.63) **	0.61 (0.59-0.62) **	0.58 (0.56-0.59) **	0.61 (0.59-0.62) **	0.58 (0.57-0.60) **	0.55 (0.53-0.56) **	0.61 (0.59-0.62) **
Elevated TG	0.69 (0.68-0.70) **	0.68 (0.67-0.69) **	0.67 (0.66-0.68) **	0.69 (0.68-0.70) **	0.63 (0.62-0.64) **	0.61 (0.6-0.62) **	0.69 (0.68-0.70) **
Reduced HDL-C	0.62 (0.61-0.63) **	0.62 (0.61-0.63) **	0.63 (0.62-0.64) **	0.62 (0.61-0.63) **	0.55 (0.54-0.57) **	0.55 (0.54-0.56) **	0.62 (0.61-0.63) **
Elevated SUA	0.69 (0.66-0.72) **	0.68 (0.66-0.71) **	0.66 (0.63-0.69) **	0.70 (0.68-0.73) **	0.66 (0.63-0.69) **	0.60 (0.58-0.63) **	0.70 (0.68-0.73) **

***P* value < 0.001.

Table 4 AUC, optimal cut-off values, sensitivity, specificity and Youden index of anthropometric indices to predict the high metabolic risk population

	< 60 years					≥ 60 years				
	AUC (95%CI)	Cut-off value	Sensitivity	Specificity	Youden index	AUC (95%CI)	Cut-off value	Sensitivity	Specificity	Youden index
Male										
WC	0.74 (0.72~0.76) **	84.45	0.71	0.66	0.36	0.73 (0.70~0.75) **	84.75	0.65	0.71	0.36
BMI	0.74 (0.72~0.76) **	24.04	0.72	0.67	0.39	0.73 (0.70~0.75) **	23.24	0.70	0.63	0.34
WHR	0.73 (0.71~0.75) **	0.88	0.80	0.54	0.33	0.70 (0.68~0.73) **	0.9	0.71	0.61	0.32
WHtR	0.73 (0.71~0.75) **	0.51	0.65	0.69	0.34	0.73 (0.70~0.75) **	0.51	0.67	0.67	0.35
BAI	0.63 (0.61~0.66) **	25.12	0.61	0.58	0.19	0.64 (0.61~0.67) **	25.24	0.69	0.53	0.22
ABSI	0.61 (0.58~0.63) **	0.08	0.68	0.50	0.19	0.60 (0.57~0.62) **	0.08	0.51	0.67	0.18
BRI	0.73 (0.71~0.75) **	3.49	0.65	0.69	0.34	0.73 (0.70~0.75) **	3.46	0.72	0.63	0.35
Female										
WC	0.73 (0.71~0.75) **	78.9	0.76	0.60	0.36	0.69 (0.67~0.71) **	78.85	0.77	0.51	0.28
BMI	0.73 (0.71~0.75) **	22.94	0.78	0.56	0.35	0.70 (0.67~0.71) **	23.73	0.62	0.65	0.28
WHR	0.71 (0.69~0.73) **	0.85	0.73	0.60	0.33	0.65 (0.63~0.67) **	0.88	0.66	0.57	0.23
WHtR	0.73 (0.71~0.75) **	0.51	0.71	0.64	0.35	0.68 (0.66~0.70) **	0.51	0.77	0.51	0.28
BAI	0.64 (0.62~0.66) **	27.89	0.76	0.44	0.21	0.61 (0.59~0.64) **	30.99	0.51	0.67	0.17
ABSI	0.62 (0.59~0.64) **	0.0763	0.63	0.56	0.18	0.55 (0.53~0.57) **	0.0781	0.71	0.39	0.1
BRI	0.73 (0.71~0.75) **	3.47	0.71	0.64	0.35	0.68 (0.66~0.70) **	3.6	0.77	0.51	0.28

**P value < 0.001.

Figure legends

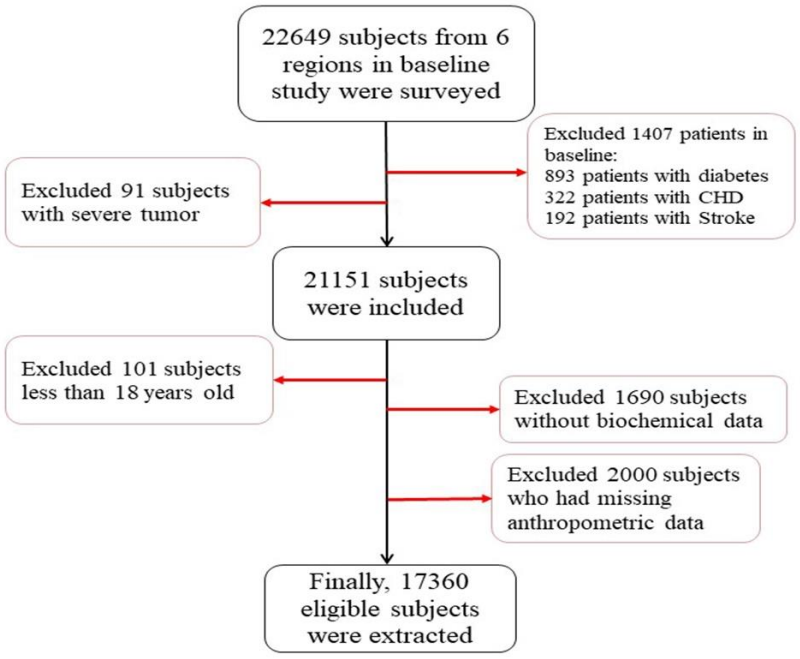

Figure 1 Flowchart of inclusion criteria for participants in this study

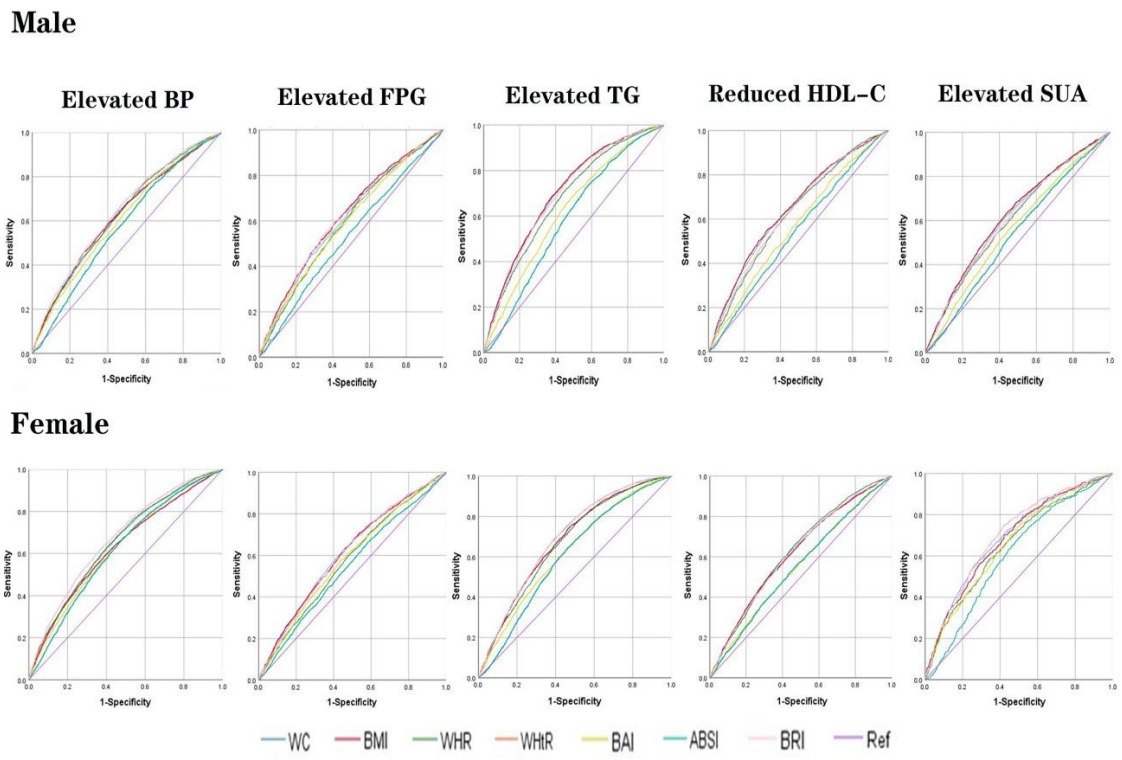

Figure 2 ROC curves of anthropometric indices to predict multi metabolic risk factors

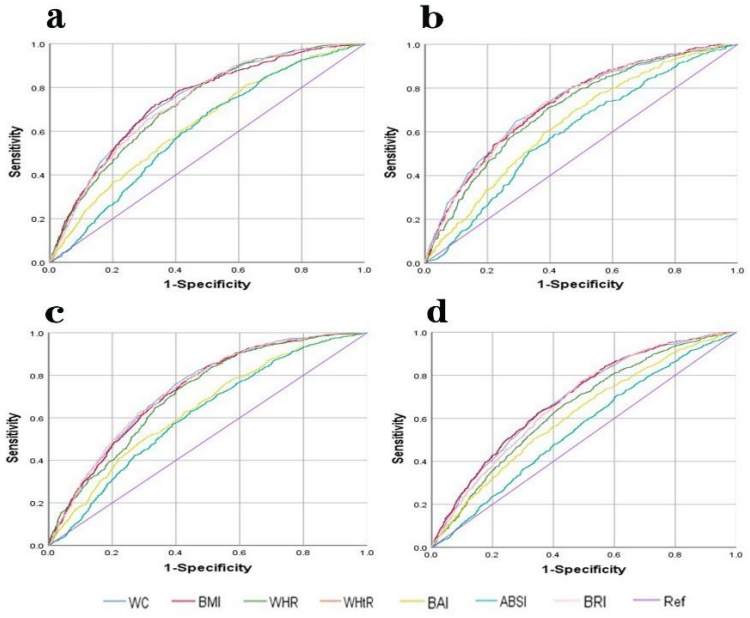

Figure 3 ROC curves of anthropometric indices to predict high metabolic risk population

(a) ROC curves in males within young (<60 years old) group

(b) ROC curves in males within elder (≥60 years old) group

(c) ROC curves in females within young (<60 years old) group

(d) ROC curves in females within elder (≥60 years old) group