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## Comparison of Anthropometric Indices for Predicting the Risk of Metabolic Syndrome and Its Components in Chinese Adults: A Prospective Study

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2017-016062
Article Type:	Research
Date Submitted by the Author:	24-Jan-2017
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<b>Primary Subject Heading</b> :	Diabetes and endocrinology
Secondary Subject Heading:	Diagnostics, Epidemiology
Keywords:	metabolic syndrome, waist circumference, abdominal volume index, visceral adiposity index, anthropometric index

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4 1 **Comparison of Anthropometric Indices for Predicting the Risk of**  
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6 2 **Metabolic Syndrome and Its Components in Chinese Adults: A**  
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8 3 **Prospective Study**

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4 455  
6 46 **Running title:** Anthropometric indices and Incident MetS7  
8 47  
910  
11 48 **Authors' statement:** The authors hereby confirm that neither the manuscript nor any part of it has  
12  
13 49 been published or is being considered for publication elsewhere. We acknowledge that all authors  
14  
15 50 participated sufficiently in the work and take public responsibility for its content.  
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20  
21 52 **Funding:**22  
23  
24 53 1. the Chinese National Natural Science Foundation (Grant: 81300645)25  
26 54 2. the National Science and Technology Support Program (Grant: 2009BAI80B00)27  
28 55  
2930  
31 56 **Disclosure Summary:** The authors have no potential conflict of interest to declare.  
32  
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34 57

35  
36 58 **Word count:** 293 (Abstract); 2943 (excluding abstract, figure captions, and references)37  
38 59  
3940  
41 60 **Figures & Tables:** 742  
43 61  
4445  
46 62  
4748  
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67 **Abstract**

68 **Background:** Our study aimed to distinguish the ability of anthropometric indices to assess the risk of  
69 metabolic syndrome (MetS) at the time of cross-section analysis and during a 4.5-year follow-up.

70 **Setting, participants and outcome measures:** Data were collected from cross-sectional and  
71 longitudinal prospective studies between 2010 and 2014. At baseline, a total of 379 individuals (198  
72 males and 181 females) were enrolled in the study. A variety of anthropometric parameters were  
73 measured, including waist circumference (WC), body mass index (BMI), a body shape index (ABSI),  
74 abdominal volume index (AVI), body adiposity index (BAI), body roundness index (BRI), conicity  
75 index (CI), waist-to-hip ratio (WHR) and visceral adiposity index (VAI). MetS was diagnosed  
76 according to the criteria of the International Diabetes Federation. Receiver operating curve (ROC)  
77 was applied to examine the potential of the above indices at baseline to identify the status and risk of  
78 MetS.

79 **Results:** At baseline, 43.9% of males and 21.5% of females suffered from MetS. All of the  
80 anthropometric indices showed clinical significance, and VAI was superior to the other indices, as it  
81 was found to have the largest area under the ROC at the time of cross-section analysis. After a  
82 4.5-year follow-up, 37.8% of males and 23.9% of females developed MetS. ROC analysis suggested  
83 that the strongest predictor of MetS was baseline BMI and AVI in males and females, respectively.  
84 However, no significant differences were observed between the two indices and WC. In contrast, the  
85 baseline ABSI did not predict MetS in both genders.

86 **Conclusions:** The present study indicated that these different indices derived from anthropometric  
87 parameters have different discriminatory abilities for MetS. Although WC did not have the largest  
88 AUC for diagnosing and predicting MetS, it may remain the better index of MetS status and risk

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4 89 because of its simplicity and wide utilization.  
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#### 91 **Strengths and limitations of this study:**

92 1. This is a longitudinal prospective study of the association of anthropometric indices with  
93 metabolic syndrome risk.

94 2. This is the first study to systematically report the different abilities of anthropometric indices in  
95 diagnosing or predicting metabolic syndrome.

96 3. The current study was limited to middle-aged and elderly subjects in northeast China.

97 4.

#### 98 **Keywords**

99 Metabolic syndrome; Waist circumference; Abdominal volume index; Visceral adiposity index;  
100 Anthropometric index.

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#### 103 **Background**

104 Metabolic syndrome (MetS) is considered as a cluster of risk factors for cardiovascular morbidity  
105 and mortality<sup>1</sup>, involving approximately 34% of adults based on the National Health and Nutrition  
106 Examination Survey<sup>2</sup>. A growing body of evidence supports the hypothesis that abdominal visceral  
107 fat plays a role in the development of MetS<sup>3-6</sup>. In this context, it is reasonable that central obesity is  
108 defined as a predictor of MetS.

109 Although the body mass index (BMI) is in widespread use, it is not an evaluation of fat  
110 distribution. Therefore, additional anthropometric indices are required to assess abdominal adipose

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4 111 accumulation. Elevated waist circumference (WC) and waist-to-hip ratio (WHR) were reported to be  
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6 112 strongly associated with central obesity and MetS<sup>7</sup>. Moreover, Krakauer's and Tomas' groups  
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8 113 proposed a body shape index (ABSI) and body adiposity index (BRI), respectively, to estimate body  
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10 114 fat distribution. However, neither of the indices above were proven to have a better correlation with  
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12 115 cardiovascular disease compared to BMI or WC<sup>8</sup>. Recently, a close association of cardiometabolic  
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14 116 risk with an alternative index, visceral adiposity index (VAI), was found<sup>9</sup>. However, the superiority  
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16 117 of its predictive value versus any other indices is unclear. Abdominal volume index (AVI) is another  
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18 118 anthropometric tool for overall volume estimation which has a strong relationship to the dysfunction  
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20 119 of glucose metabolism, according to the author<sup>10</sup>. Additionally, other indices have been used, such as  
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22 120 conicity index (CI) and body adiposity index (BAI), to improve on commonly used methods<sup>11 12</sup>.  
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26 121 However, a comprehensive consensus has not been reached about the best indices for evaluating the  
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28 122 status and risk of MetS.

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33 123 Accumulating evidence has indicated the different association of these indices with MetS, and  
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35 124 most the studies were cross-sectional. Thus, we compared the predictive ability of anthropometric  
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37 125 indices including WC, BMI, ABSI, AVI, BAI, BRI, CI, WHR, and VAI, using a prospective study.  
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## 127 **Methods**

### 128 **Study Population**

129 To evaluate the effectiveness of anthropometric indices in predicting MetS, a community-based study  
130 was performed between 2010 and 2014 in urban Shenyang, Liaoning Province, China. Individuals  
131 with malignancy and severe liver or renal diseases were excluded. During the follow-up period,  
132 new-onset MetS subjects with a history of drugs or surgeries for weight reduction, lipid reduction, or

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4 133 treatments for diabetes or hypertension during follow-up were also excluded. Finally, data from 379  
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6 134 participants (198 males and 181 females) aged 40-65 were selected for this study, and the average  
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9 135 follow-up duration was 4.5 years (Figure 1).

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11 136 This study was approved by the Ethics Committee of the First Affiliated Hospital of China  
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14 137 Medical University, and all participants provided signed informed consent before enrollment in this  
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16 138 study.  
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#### 20 21 140 **Data Measurement and Collection**

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24 141 At baseline and at the endpoint, all subjects underwent comprehensive interviews and health  
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26 142 examinations by trained staff. A questionnaire including demographic characteristics, personal  
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29 143 medical history, and information related to the diagnosis and treatment of MetS was completed for  
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31 144 each participant. Based on the previous standardized protocol<sup>13</sup>, body weight, height, waist  
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34 145 circumference (WC), hip circumference (HC), systolic blood pressure (SBP), and diastolic blood  
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36 146 pressure (DBP) were measured. Participants were given a standard 75-g oral glucose tolerance test  
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39 147 (OGTT). Venous blood samples were drawn to determine fasting plasma glucose (FPG), plasma  
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41 148 glucose 2 hours after a glucose load (2 h PG), fasting plasma insulin (FINS), total cholesterol (TC),  
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44 149 triglycerides (TG), high-density lipoprotein cholesterol (HDL), and low-density lipoprotein  
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46 150 cholesterol (LDL) according to standard methods.  
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49 151 At baseline, all subjects had magnetic resonance imaging scans performed at the abdominal level  
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51 152 between the 4<sup>th</sup> and 5<sup>th</sup> lumbar vertebrae in the prone position (FOV 42 cm×42 cm, thickness 1 cm, 6  
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54 153 layers, GE, USA). Subcutaneous fat area (SFA) and visceral fat area (VFA) were calculated using  
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56 154 SLICE-O-MATIC version4.2 software (Tomovision) by two separate technicians.  
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### 156 **Metabolic Syndrome Definition**

157 The diagnose of MetS was diagnosed based on the International Diabetes Federation criteria, which  
 158 include three or more risk characteristics<sup>7 14</sup>, including 1.) abdominal obesity (WC≥90 cm for males,  
 159 85 cm for females), 2.) elevated TG (TG≥1.70 mmol/L), 3.) low HDL (HDL-c<1.0 mmol/L for males,  
 160 <1.3 for females), 4.) high blood pressure (SBP≥130 mmHg, DBP≥85 mmHg, or a history of  
 161 hypertension), or 5.) elevated plasma glucose (FPG≥5.6 mmol/L, or a diagnosis of T2DM).

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### 163 **Calculations**

164 The homeostatic model assessment index for insulin resistance (HOMA-IR) was evaluated using the  
 165 formula: HOMA-IR = FPG (mmol/L)×FINS (mIU/L)/22.5. The anthropometric indices, such as BMI,  
 166 WHR, ABSI, AVI, BAI, BRI, CI, and VAI were calculated using the following formulas:

$$167 \quad BMI = \frac{Weight}{Height^2}$$

$$168 \quad WHR = \frac{WC}{HC}$$

$$169 \quad ABSI = \frac{WC}{BMI^{\frac{2}{3}} \times Height^{\frac{1}{2}}}$$

$$170 \quad AVI = \frac{2 \times WC^2 + 0.7 \times (WC - HC)^2}{1000}$$

$$BAI = \frac{HC}{Height^{\frac{3}{2}}} - 18$$

171

$$BRI = 364.2 - 365.5 \times \sqrt{1 - \frac{(WC/2\pi)^2}{(0.5 \times Height)^2}}$$

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$$CI = \frac{WC}{0.109 \times \sqrt{\frac{Weight}{Height}}}$$

173

$$VAI_{male} = \left(\frac{WC}{39.68} - 1.88 \times BMI\right) \times \frac{TG}{1.03} \times \frac{1.31}{HDL}$$

174

$$VAI_{female} = \left(\frac{WC}{36.58} - 1.89 \times BMI\right) \times \frac{TG}{0.81} \times \frac{1.52}{HDL}$$

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## 176 **Statistical Analyses**

177 Based on the diagnosis of MetS, the subjects were assigned to MetS or non-MetS groups at baseline.

178 Individuals without MetS at baseline were further divided into newly MetS or free-MetS groups

179 according to whether or not they developed MetS during follow-up.

180 The data distribution was assessed using the Kolmogorov-Smirnov test. The variables were

181 displayed as the mean±standard deviations, medians (interquartile range) or counts (percentages)

182 according to their types. Univariate analyses were conducted to estimate the relative factors of MetS

183 and its components using the *t*-test, Mann-Whitney rank sum test, Pearson's Chi-squared test, or

184 Fisher's exact test depending on the characteristics of the data. The ability of the anthropometric

185 indices to identify individuals with MetS was evaluated by the area under receiver operating

186 characteristic (ROC) curves, and the new cutoff points were suggested by Youden's Index

187 (sensitivity+specificity-1). Statistical analyses were performed using SPSS (version 23.0, IBM Corp.,

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4 188 USA). MedCalc (version 16.2, MedCalc Software, Belgium) was used to analyze the ROC curves.

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6 189 Statistical significance was defined as  $P < 0.05$  for all analyses.

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## Results

### 192 **Baseline characteristics of the participants**

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16 193 At baseline, 87 (43.9%) males and 39 (21.5%) females were diagnosed with MetS. The median age  
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18 194 of study subjects was 49.5 (45.0-55.0) for males and 47.0 (44.0-54.0) for females. Compared with  
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21 195 the non-MetS group, subjects with MetS had significantly higher levels of SBP, DBP, FPG, 2 h PG,  
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23 196 FIN, HbA1c, TG, LDL, HOMA-IR, SFA, and VFA, but lower levels of HDL. TC was significantly  
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25 197 increased in males with MetS, while no significant difference was observed in females. Furthermore,  
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27 198 all of the nine anthropometric indices, including WC, BMI, WHR, ABSI, AVI, BAI, BRI, CI, and  
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29 199 VAI, were elevated significantly in both males and females of the MetS group (**Table 1**).

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34 200 In the non-MetS group, 42 (37.8%) males and 34 (23.9%) females developed MetS after 4.5-years  
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36 201 of follow-up. Compared to the healthy controls, TG, SFA, and VFA were significantly elevated in the  
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38 202 newly MetS group. Furthermore, females in the newly MetS group had increased baseline levels of  
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40 203 SBP, DBP, 2 h PG, and LDL but lower levels of HDL. Considering anthropometric indices, WC,  
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42 204 BMI, WHR, AVI, BRI, CI, and VAI were higher in males and females of the newly MetS group. The  
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44 205 females who developed MetS had a higher baseline BAI, while no significant difference was  
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46 206 observed between free-MetS and newly MetS in males. Additionally, there was no difference in  
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48 207 ABSI of both males and females between the free-MetS and newly MetS groups (**Table 2**).

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### 209 **Comparison of the anthropometric indices for diagnosing MetS at baseline**

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4 210 At baseline, the areas under the ROC curves (AUCs) of all the anthropometric indices were larger  
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6 211 than 0.5 ( $P<0.05$ ), suggesting their clinical diagnostic significance for MetS (**Table 3**). Our results  
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8 212 showed that the VAI had the largest AUC for both genders [0.85 (0.79-0.92) for males and 0.90  
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10 213 (0.84-0.96) for females]. The BAI [0.67 (0.59-0.75)] and ABSI [0.62 (0.52-0.72)] showed the lowest  
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12 214 AUCs for males and females, respectively. In males, AVI, BRI, CI, and VAI had approximately the  
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14 215 same AUCs as WC for diagnosing MetS (all  $P>0.05$  vs. WC). However, the AUCs of BMI, WHR,  
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16 216 ABSI, and BAI were significantly lower compared with WC for males (all  $P<0.05$  vs. WC). In  
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18 217 females, the AUC of VAI was significantly larger than WC, while the AUCs of ABSI, BAI, and CI  
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20 218 were significantly lower (all  $P<0.05$  vs. WC). The other five anthropometric indices showed no  
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22 219 significant differences in diagnosing MetS in females (all  $P>0.05$  vs. WC).  
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### 31 **Comparison of the anthropometric indices for predicting MetS during follow-up**

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33 222 In general, the AUCs varied from 0.58 (0.49-0.68) for ABSI to 0.77 (0.68-0.85) for BMI in males  
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35 223 and from 0.55 (0.47-0.64) for ABSI to 0.72 (0.64-0.79) for AVI in females. In addition, the AUC of  
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37 224 ABSI was the lowest and did not differ from 0.5 in both males and females ( $P>0.05$ ). Moreover, the  
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39 225 AUC of BAI was significantly larger than 0.5 in males, while no difference from 0.5 was observed in  
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41 226 females. All the AUCs of the other indices were greater than 0.5 ( $P<0.05$ ), suggesting their clinical  
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43 227 predictive significance for MetS. In males, the AUC of BMI did not differ significantly from WC,  
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45 228 although BMI had the largest AUC. The other indices, including WHR, AVI, and BRI, also showed  
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47 229 no significant differences when compared with WC. Furthermore, ABSI, BAI, CI and VAI had  
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49 230 significantly lower AUCs than WC. In females, no significant differences were observed between  
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51 231 WC and BMI, WHR, AVI, BAI, BRI, CI, or VAI. Moreover, ABSI had a significantly lower AUC  
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6 233 Other details of all the anthropometric indices such as cutoff, sensitivity, specificity, Youden index,  
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9 234 positive predictive value (PPV), and negative predictive value (NPV) were also reported in this study  
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11 235 (**Table 4**).

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### 15 16 237 **AUCs of the anthropometric indices for predicting MetS components during follow-up**

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18 238 Compared with females, the morbidities of MetS, high TG and high BG in males were elevated (37.8%  
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21 239 vs. 23.9%, 19.2% vs. 8.5%, and 24.8% vs. 14.3%, respectively) after a 4.5-year follow-up.  
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24 240 Morbidities of the other two MetS components showed no differences between males and females  
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26 241 (**Table S1**). Furthermore, we made comparisons of all indices in predicting MetS components (**Table**  
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29 242 **5** and **Table 6**). First, the AUCs of all the indices had predictive significance for central obesity in  
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31 243 males, except ABSI, BAI, CI and VAI. Additionally, the AUCs of ABSI, CI and VAI were not  
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34 244 significantly larger than 0.5 in females. The AUC of VAI was not significantly different from WC,  
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36 245 although AVI had the largest AUC for incident central obesity in males and females. Second, none of  
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39 246 the anthropometric indices showed significance for predicting high TG in males or females, except  
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41 247 for BMI and VAI in males. Moreover, the AUCs of all the indices were small for predicting low HDL  
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44 248 and high BG, and none were significantly over 0.5. Therefore, none of the indices could discriminate  
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46 249 among both males and females with low HDL or high BG. Lastly, either BAI or VAI had an AUC  
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49 250 less than 0.5 for high BP in males, and the AUCs of WHR, ABSI, and VAI were significantly less  
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51 251 than 0.5 in females. Furthermore, WC and AVI had the largest AUCs for high BP in males, and no  
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54 252 difference was observed between these two indices. In females, the AUC of AVI was the largest for  
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56 253 high BP in females but did not differ significantly from WC.

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6 255**Dicussion**

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9 256 A variety of investigations have evaluated the discriminatory ability of indices derived from several  
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11 257 anthropometric parameters in MetS. Most of these studies were cross-sectional. In this study, we  
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13 258 compared nine obesity indices, including WC, BMI, WHR, ABSI, AVI, BAI, BRI, CI, and VAI, in  
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15 259 assessing the incident risk of MetS using a 4.5-year prospective analysis. Our study indicated that  
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17 260 some novel anthropometric indices may be insufficient for evaluating the incident risk of MetS.

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21 261 At baseline, all the indices showed significant roles in diagnosing MetS, and VAI had the highest  
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23 262 AUC value in both males and females. For the calculation of the VAI value involving WC, BMI, TG,  
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25 263 and HDL, it is suggested that VAI might provide a broader evaluation of metabolic risk related to  
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27 264 visceral fat dysfunction. A previous study has reported that VAI has significant advantages over WC  
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29 265 for determining cardiometabolic risk<sup>9</sup>, even though a study in young adults has indicated that VAI did  
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31 266 not provide better power than WC or BMI in the assessment of visceral adiposity<sup>15</sup>. In our study, VAI  
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33 267 was the best surrogate marker of MetS, especially considering the significant, excessive AUC in  
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35 268 females.

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41 269 Furthermore, we compared the AUCs of all the anthropometric indices for predicting MetS and its  
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43 270 components. In general, ABSI was the worst predictive index for both genders. Previously, a few  
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45 271 cross-sectional studies proved that ABSI was a weak index for MetS risk<sup>16,17</sup>. Our results confirmed  
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47 272 this finding using prospective evidence. Furthermore, different from the cross-sectional study, the  
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49 273 AUC of VAI was less than WC and even had a significant difference in males. In 2014, Chen *et al.*  
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51 274 suggested that VAI shows a similar predictive performance for all-cause mortality to WC in ROC  
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53 275 analysis<sup>18</sup>, suggesting that VAI as a predictor of MetS is not superior or even equal to WC.

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4 276 Additionally, BMI and AVI showed the strongest ability in the prediction of MetS for males and  
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6 277 females, respectively. However, there was no significant difference between the two indices above  
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9 278 and WC. Thus, WC appeared to be a more useful predictor of MetS in clinical practice for its  
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11 279 simplicity and widespread utilization.

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14 280 Our study also proposed optimal cutoff points for these anthropometric indices. An obvious  
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16 281 difference between two genders was observed in WC, WHR, ABSI, BAI and VAI, suggesting that  
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18 282 gender-based measures should be used in clinical practice. Notably, the present results showed that  
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21 283 the optimal cutoff points for WC are considerably different from the cutoff points according to the  
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23 284 guideline on prevention and treatment of metabolic dysfunction in Chinese adults<sup>19</sup>. Therefore, it  
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25 285 may be optimal that decreased WC cutoffs are used in the clinical setting to select Chinese adults at  
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28 286 high risk of incident MetS. Additionally, all the PPVs of indices were less than NPV, suggesting that  
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31 287 the indices covered in this article were suitable for identifying individuals without a risk for MetS in  
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33 288 a non-MetS population.

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36 289 Our study further finds that the indices show different discriminatory power for different MetS  
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38 290 components. AVI had the largest AUC for central obesity in both males and females. On the other  
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41 291 hand, VAI of males had the highest AUC value for high TG and high BP. In females, the AUC of AVI  
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43 292 for high BP was larger than the other indices, while no indicator showed significance in predicting  
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45 293 high TG in females. Interestingly, the CI played only a predictive role of new-onset high BP in both  
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48 294 genders, suggesting a worse predictive ability for MetS components. This is probably because weight  
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51 295 dilutes the influence of height according to its formula<sup>20</sup>. Additionally, all the indices failed in  
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53 296 forecasting incident low HDL and high BG, in contrast to other studies<sup>8 9 21 22</sup>. One possible  
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56 297 explanation is that only a few individuals developed low HDL and high BG, and the small sample  
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4 298 size may impact the reliability of results. In summary, the results above suggest that the current  
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6 299 indicators of anthropometric indices cannot provide a comprehensive prediction of metabolic risk  
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9 300 factors. Accordingly, further study to clarify the association of anthropometric parameters with MetS  
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11 301 components is necessary.

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14 302 Several limitations of the present study should be considered. First, this study was limited to  
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16 303 middle-aged and elderly subjects in northeast China. Hence, the applicability of these results may be  
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18 304 limited for other populations. Second, only the baseline anthropometric parameters were used in the  
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20 305 study, although lifestyle modification may have an impact on the chronological changes of obesity  
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22 306 indices. However, our study aims to assess the predictive abilities of anthropometric indices at  
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24 307 baseline in a prospective cohort. Therefore, it is likely that the anthropometric changes during  
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26 308 follow-up period had little effect on the current results.

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### 32 33 34 310 **Conclusions**

35  
36 311 In conclusion, VAI is the best index for diagnosis of MetS in this cross-section. Moreover, although  
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38 312 no obvious advantages were observed for WC, BMI and AVI are superior to the other anthropometric  
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40 313 indices for predicting MetS in males and females, respectively. However, considering the simplicity  
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42 314 and wide utilization, WC remains the more practical discriminator for MetS.

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### 47 48 316 **Abbreviations**

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51 317 MetS: metabolic syndrome; WC: waist circumference; BMI: body mass index; ABSI: a body shape  
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53 318 index; AVI: abdominal volume index; BAI: body adiposity index; BRI, body roundness index; CI,  
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55 319 conicity index; WHR: waist-to-hip ratio; VAI: visceral adiposity index; ROC: Receiver operating

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4 320 curve; HC: hip circumference; SBP: systolic blood pressure; DBP: diastolic blood pressure; OGTT:  
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6 321 75g oral glucose tolerance test; FPG: fasting plasma glucose; 2hPG: plasma glucose 2 hours after a  
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9 322 glucose load; FINS: fasting plasma insulin; TC: total cholesterol; TG: triglycerides; HDL:  
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11 323 high-density lipoprotein cholesterol; LDL: low-density lipoprotein cholesterol; SFA: subcutaneous  
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14 324 fat area; VFA: visceral fat area; HOMA-IR: the homeostatic model assessment index for insulin  
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16 325 resistance; PPV: positive predictive value; NPV: negative predictive value.  
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### 327 **Declarations**

### 328 **Acknowledgements**

329 We thank the participants and staff at the Institute of Endocrinology of the First Affiliated Hospital  
330 of China Medical University for their involvement in this study.  
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### 332 **Contributors**

333 Haoyu Wang was the primary investigator, and reviewed the literatures, performed this follow-up  
334 project, collected data, analyzed results, and produced the first draft of manuscript; Aihua Liu  
335 reviewed the literature, interpreted the data, and edited the manuscript; Tong Zhao, Xun Gong,  
336 Tianxiaopang, Yingying Zhou, Yue Xiao, Yumeng Yan, and Chenlin Fan participated in this  
337 follow-up project, collected and interpreted data; Weiping Teng supervised the statistical analyses,  
338 and edited the manuscript; Zhongyan Shan supervised the statistical analyses, and produced the final  
339 version of the manuscript. All authors read and approved the final manuscript.  
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### 341 **Funding**

1  
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4 342 This work was supported by the Chinese National Natural Science Foundation (Grant: 81300645)  
5  
6 343 and the National Science and Technology Support Program (Grant: 2009BAI80B00). The funders  
7  
8 344 had no roles in the study design, data collection or analysis, or the presentation or publication of the  
9  
10  
11 345 results.

### 12 13 346 14 15 16 347 **Competing interests**

17  
18 348 The authors declare that they have no competing interests.

### 19 20 349 21 22 23 24 350 **Ethics approval**

25  
26 351 This study was approved by the Ethics Committee of the First Affiliated Hospital of China Medical  
27  
28 352 University. Informed consent was obtained from all individual participants included in the study.

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### Figure Caption

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26 417 **Figure 1.** Flow graph of individual recruitment.  
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### Tables

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49 426 **Table 1.** Baseline characteristics of study subjects according to the MetS status at baseline.  
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Characteristics	Male (n=198)			Female (n=181)		
	non-MetS	MetS	<i>P</i>	non-MetS	MetS	<i>P</i>
N (%)	111 (56.1)	87 (43.9)		142 (78.5)	39 (21.5)	
Age (yr)	49.0	50.0	0.397	47.5	47.0	0.515
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	(44.0-55.0)	(46.0-56.0)		(43.0-54.0)	(46.0-56.0)	
	123.3	136.7		116.7	134.0	
SBP (mmHg)			<0.001			<0.001
	(117.3-131.3)	(125.3-146.7)		(108.7-123.7)	(120.0-148.0)	
	80.0	87.3		76.3	88.7	
DBP (mmHg)			<0.001			<0.001
	(85.3-73.3)	(83.3-94.0)		(69.3-80.2)	(92.7-80.0)	
FPG (mmol/L)	5.3 (5.0-5.7)	6.1 (5.4-7.2)	<0.001	5.3 (5.0-5.5)	5.8 (5.2-7.8)	<0.001
2hPG (mmol/L)	6.3 (5.2-7.5)	9.3 (6.8-12.3)	<0.001	6.8 (5.9-7.9)	9.6 (7.8-12.6)	<0.001
	12.49	16.77		15.54	25.05	
FINS (mIU/L)			<0.001			<0.001
	(9.24-17.75)	(12.87-24.63)		(12.50-19.69)	(18.65-30.54)	
HbA1c (%)	5.7 (5.4-6.0)	6.0 (5.6-6.7)	<0.001	5.9 (5.5-6.2)	6.2 (5.7-7.2)	0.005
TC (mmol/L)	4.8 (4.3-5.3)	5.3 (4.7-5.9)	0.001	5.1 (4.5-5.5)	5.2 (4.4-5.9)	0.494
TG (mmol/L)	1.3 (0.9-1.6)	2.4 (2.0-3.6)	<0.001	1.1 (0.9-1.5)	2.4 (1.7-3.8)	<0.001
HDL (mmol/L)	1.3 (1.1-1.5)	1.1 (0.9-1.3)	<0.001	1.5 (1.3-1.8)	1.1 (1.0-1.4)	<0.001
LDL (mmol/L)	3.0 (2.6-3.5)	3.1 (2.7-3.8)	0.148	3.1 (2.6-3.6)	3.2 (2.6-3.6)	0.963
	2.98	4.74		3.79	6.83	
HOMA-IR			<0.001			<0.001
	(2.23-4.46)	(3.69-6.72)		(2.81-4.86)	(4.17-8.30)	
Current Smoking, n (%)	75(67.57)	51(58.62)	0.194	7(4.93)	1(2.56)	0.844
Alcohol Intake, n (%)	39(35.14)	41(47.13)	0.088	3(2.11)	1(2.56)	1.000
SFA (cm <sup>2</sup> )	124.62±49.88	151.84±51.80	0.001	178.86±65.82	226.87±69.24	<0.001
VFA (cm <sup>2</sup> )	84.40±45.85	116.39±44.40	<0.001	57.76±24.16	91.80±32.98	<0.001
WC (cm)	87.3±8.1	94.7±7.9	<0.001	80.3±8.6	89.0±7.9	<0.001
BMI (kg/m <sup>2</sup> )	24.6±2.8	26.6±2.8	<0.001	23.9±3.0	27.1±3.4	<0.001
WHR	0.90±0.05	0.94±0.05	<0.001	0.85±0.06	0.90±0.05	<0.001
ABSI (m <sup>7/6</sup> /kg <sup>2/3</sup> )	0.0792±0.0033	0.0814±0.0034	<0.001	0.0770±0.0041	0.0784±0.0036	0.040
	15.24	17.86		13.10	15.51	
AVI (cm <sup>2</sup> )			<0.001			<0.001
	(13.48-17.03)	(16.31-20.10)		(11.56-14.30)	(14.62-17.79)	
BAI (0.01m <sup>-0.5</sup> )	25.84±3.01	27.33±2.68	<0.001	29.30±3.18	31.70±3.22	<0.001

BRI	3.65±0.95	4.49±0.98	<0.001	3.50±0.96	4.63±1.03	<0.001
CI (m <sup>2</sup> /kg <sup>1/2</sup> )	1.24±0.06	1.29±0.06	<0.001	1.20±0.07	1.25±0.06	<0.001
VAI	1.30 (0.94-1.84)	3.24 (2.17-4.63)	<0.001	1.43 (0.96-1.96)	4.30 (2.46-6.35)	<0.001

Abbreviations: SBP, systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose; 2hPG, 2 hours after glucose-load plasma glucose; FINS, fasting plasma insulin; TC, total cholesterol; TG, triglycerides; HDL, high density lipoprotein cholesterol; LDL, low density lipoprotein cholesterol; SFA, subcutaneous fat area; VFA, visceral fat area; BMI, body mass index; WHR, waist-to-hip ratio; ABSI, a body shape index; AVI, abdominal volume index; BAI, body adiposity index; BRI, body roundness index; CI, conicity; VAI, visceral adiposity index.

**Table 2.** Baseline characteristics of healthy subjects who developed MetS or not at follow-up.

Characteristics	Male (n=111)			Female (n=142)		
	free-MetS	newly-MetS	<i>P</i>	free-MetS	newly-MetS	<i>P</i>
N (%)	69 (62.2)	42 (37.8)		108 (76.1)	34 (23.9)	
Age (yr)	49.0 (45.0-55.5)	50.5 (41.8-55.0)	0.549	47.0 (44.0-53.0)	48.5 (42.0-56.3)	0.754

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4	SBP (mmHg)	122.0	125.0	0.239	113.3	120.0
5		(114.3-132.7)	(119.3-130.7)		(105.3-122.7)	(116.5-126.8)
6						0.003
7	DBP (mmHg)	80.0 (71.7-85.7)	80.0 (77.2-85.7)	0.314	74.7 (68.0-80.0)	79.0 (76.0-82.0)
8						< 0.001
9	FPG (mmol/L)	5.3 (4.9-5.6)	5.4 (5.1-5.9)	0.149	5.3 (5.0-5.5)	5.3 (5.0-5.6)
10						0.274
11	2hPG (mmol/L)	6.2 (5.3-7.5)	6.3 (5.1-8.4)	0.584	6.6 (5.8-7.6)	7.9 (6.9-9.5)
12						< 0.001
13						
14					15.32	16.15
15	FINS (mIU/L)	12.18 (8.85-16.46)	12.60 (9.92-20.42)	0.341	(12.02-19.81)	(13.33-19.38)
16						0.374
17	HbA1c (%)	5.6 (5.4-5.8)	5.7 (5.4-6.2)	0.131	5.8 (5.5-6.1)	6.1 (5.6-6.3)
18						0.062
19	TC (mmol/L)	4.7 (4.3-5.3)	4.9 (4.3-5.5)	0.302	5.1 (4.5-5.5)	5.1 (4.6-5.9)
20						0.426
21	TG (mmol/L)	1.2 (0.9-1.6)	1.4 (1.1-1.7)	0.041	1.1 (0.8-1.5)	1.3 (1.0-1.7)
22						0.028
23	HDL (mmol/L)	1.3 (1.1-1.5)	1.2 (1.1-1.4)	0.075	1.6 (1.3-1.8)	1.5 (1.3-1.7)
24						0.029
25	LDL (mmol/L)	3.0±0.8	3.2±0.9	0.286	3.1±0.8	3.4±0.9
26						0.033
27	HOMA-IR	2.89 (2.20-3.92)	3.24 (2.25-4.91)	0.171	3.62 (2.75-4.78)	4.08 (3.13-5.07)
28						0.128
29	Current					
30	Smoking, n (%)	45 (65.22)	30 (71.43)	0.498	4 (3.70)	3 (8.82)
31						0.358
32						
33	Alcohol Intake,					
34	n (%)	22 (31.88)	17 (40.48)	0.358	3 (2.78)	0 (0.00)
35						1.000
36	SFA (cm <sup>2</sup> )	110.19±44.09	149.19±50.11	< 0.001	169.42±61.17	207.78±71.90
37						0.003
38	VFA (cm <sup>2</sup> )	67.70±33.78	112.83±49.98	< 0.001	54.96±23.79	66.34±23.58
39						0.018
40	WC (cm)	84.5±7.5	91.9±6.9	< 0.001	78.9±8.3	84.7±8.1
41						< 0.001
42	BMI (kg/m <sup>2</sup> )	23.6±2.6	26.2±2.5	< 0.001	23.4±2.9	25.4±2.8
43						0.001
44	WHR	0.88±0.05	0.92±0.05	< 0.001	0.84±0.06	0.87±0.05
45						0.003
46	ABSI					
47	(m <sup>7/6</sup> /kg <sup>2/3</sup> )	0.0788±0.0030	0.0799±0.0036	0.090	0.0767±0.0038	0.0779±0.0047
48						0.119
49	AVI (cm <sup>2</sup> )	14.18(12.89-16.23)	16.21(15.13-18.57)	< 0.001	12.46(10.91-14.18)	13.95(13.31-15.89)
50						< 0.001
51	BAI (0.01m <sup>-0.5</sup> )	25.38±2.53	26.60±3.58	0.058	28.98±2.99	30.31±3.59
52						0.033
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BRI	3.35±0.85	4.41±0.90	< 0.001	3.34±0.90	4.02±1.00	< 0.001
CI (m <sup>2</sup> /kg <sup>1/2</sup> )	1.22±0.06	1.26±0.06	0.001	1.19±0.06	1.22±0.07	0.007
VAI	1.17(0.84-1.70)	1.52(1.19-2.09)	0.009	1.35(0.86-1.83)	1.68(1.39-2.25)	0.004

443 Abbreviations: SBP, systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose; 2hPG, 2  
 444 hours after glucose-load plasma glucose; FINS, fasting plasma insulin; TC, total cholesterol; TG, triglycerides;  
 445 HDL, high density lipoprotein cholesterol; LDL, low density lipoprotein cholesterol; SFA, subcutaneous fat area;  
 446 VFA, visceral fat area; BMI, body mass index; WHR, waist-to-hip ratio; ABSI, a body shape index; AVI,  
 447 abdominal volume index; BAI, body adiposity index; BRI, body roundness index; CI, conicity; VAI, visceral  
 448 adiposity index.

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460 **Table 3.** AUCs of anthropometric indices in diagnosing of MetS at baseline.

Indices	Male			Female		
	AUC	95%CI	<i>P</i>	AUC	95%CI	<i>P</i>

WC	0.79	(0.72-0.86)	<0.001	0.79	(0.71-0.87)	<0.001
BMI	0.73 <sup>a</sup>	(0.65-0.80)	<0.001	0.75	(0.67-0.84)	<0.001
WHR	0.72 <sup>a</sup>	(0.64-0.79)	<0.001	0.75	(0.67-0.83)	<0.001
ABSI	0.70 <sup>a</sup>	(0.62-0.78)	<0.001	0.62 <sup>a</sup>	(0.52-0.72)	0.031
AVI	0.79	(0.72-0.86)	<0.001	0.79	(0.71-0.87)	<0.001
BAI	0.67 <sup>a</sup>	(0.59-0.75)	<0.001	0.69 <sup>a</sup>	(0.59-0.79)	<0.001
BRI	0.76	(0.69-0.83)	<0.001	0.80	(0.71-0.88)	<0.001
CI	0.76	(0.68-0.83)	<0.001	0.73 <sup>a</sup>	(0.64-0.82)	<0.001
VAI	0.85	(0.79-0.92)	<0.001	0.90 <sup>a</sup>	(0.84-0.96)	<0.001

461 a, vs WC,  $P < 0.05$ .

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473 **Table 4.** AUCs, optimal cutoff, sensitivity, specificity, positive and negative predictive value for the anthropometric indices in ROC analysis for  
 474 predicting MetS.

Anthropometric Indices	AUC (95%CI)	<i>P</i>	Cut-off	Sensitivity	Specificity	Youden Index	PPV	NPV
Male								
WC	0.76 (0.67-0.84)	<0.001	84.0	0.95	0.54	0.49	0.56	0.95
BMI	0.77 (0.68-0.85)	<0.001	24.94	0.69	0.75	0.44	0.63	0.80
WHR	0.73 (0.64-0.81)	<0.001	0.89	0.76	0.64	0.40	0.56	0.81
ABSI	0.58 <sup>a</sup> (0.49-0.68)	0.149	0.0822	0.29	0.88	0.17	0.60	0.67
AVI	0.76 (0.67-0.84)	<0.001	14.25	0.95	0.54	0.49	0.56	0.95
BAI	0.59 <sup>a</sup> (0.49-0.68)	0.124	27.44	0.40	0.87	0.27	0.65	0.70
BRI	0.74 (0.65-0.82)	<0.001	3.47	0.81	0.58	0.39	0.54	0.83
CI	0.67 <sup>a</sup> (0.58-0.76)	<0.001	1.21	0.83	0.45	0.28	0.48	0.81
VAI	0.65 <sup>a</sup> (0.55-0.74)	0.005	1.06	0.83	0.48	0.31	0.49	0.82
Female								
WC	0.71 (0.64-0.79)	<0.001	80.0	0.82	0.60	0.42	0.39	0.91
BMI	0.71 (0.63-0.78)	<0.001	25.14	0.59	0.78	0.37	0.46	0.86
WHR	0.68 (0.59-0.75)	<0.001	0.81	0.91	0.37	0.28	0.31	0.93
ABSI	0.55 <sup>a</sup> (0.47-0.64)	0.358	0.0799	0.32	0.81	0.13	0.35	0.79

AVI	0.72 (0.64-0.79)	<0.001	13.03	0.82	0.60	0.42	0.39	0.91
BAI	0.64 (0.56-0.72)	0.013	30.38	0.53	0.74	0.27	0.39	0.83
BRI	0.71 (0.63-0.79)	<0.001	3.58	0.71	0.66	0.37	0.40	0.88
CI	0.63 (0.54-0.71)	0.020	1.23	0.44	0.81	0.25	0.42	0.82
VAI	0.66 (0.58-0.74)	0.001	1.36	0.79	0.52	0.31	0.34	0.89

475 a, vs WC,  $P < 0.05$ .

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486 **Table 5.** Comparison of AUCs for anthropometric indices in predicting MetS and its components in males.

Component	Central obesity		High TG		Low HDL		High BP		High BG	
	AUC (95%CI)	<i>P</i>	AUC (95%CI)	<i>P</i>	AUC (95%CI)	<i>P</i>	AUC (95%CI)	<i>P</i>	AUC (95%CI)	<i>P</i>
WC	0.79 (0.69-0.89)	<0.001	0.63 (0.47-0.78)	0.118	0.45 (0.31-0.59)	0.523	0.77 (0.66-0.88)	<0.001	0.57 (0.43-0.70)	0.348
BMI	0.78 (0.67-0.89)	<0.001	0.69 (0.55-0.84)	0.016	0.53 (0.39-0.68)	0.675	0.72 (0.60-0.84)	<0.001	0.58 (0.45-0.71)	0.263
WHR	0.71 (0.59-0.83)	0.002	0.61 (0.46-0.76)	0.185	0.41 (0.26-0.57)	0.286	0.75 (0.64-0.86)	<0.001	0.59 (0.46-0.72)	0.199
ABSI	0.50 <sup>a</sup> (0.37-0.63)	0.996	0.47 (0.29-0.64)	0.665	0.37 (0.22-0.51)	0.104	0.72 (0.61-0.84)	<0.001	0.53 (0.38-0.68)	0.677
AVI	0.79 (0.69-0.89)	<0.001	0.62 (0.47-0.78)	0.123	0.45 (0.31-0.59)	0.555	0.77 (0.66-0.88)	<0.001	0.57 (0.43-0.70)	0.348
BAI	0.57 <sup>a</sup> (0.42-0.71)	0.340	0.60 (0.43-0.77)	0.217	0.56 (0.40-0.71)	0.502	0.63 <sup>a</sup> (0.51-0.75)	0.058	0.54 (0.40-0.68)	0.554
BRI	0.70 <sup>a</sup> (0.58-0.82)	0.004	0.65 (0.50-0.80)	0.060	0.48 (0.34-0.61)	0.776	0.75 (0.64-0.86)	<0.001	0.58 (0.45-0.72)	0.226
CI	0.60 <sup>a</sup>	0.139	0.54	0.604	0.39	0.181	0.76	<0.001	0.55	0.465

	(0.48-0.73)		(0.37-0.71)		(0.25-0.53)		(0.65-0.87)		(0.41-0.69)
	0.58 <sup>a</sup>		0.69		0.61		0.61 <sup>a</sup>		0.56
VAI	0.266		0.016		0.179		0.113		0.365
	(0.45-0.70)		(0.57-0.82)		(0.45-0.77)		(0.48-0.74)		(0.43-0.70)

a, vs WC,  $P < 0.05$ .

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500 **Table 6.** Comparison of AUCs for anthropometric indices in predicting MetS and its components in females.

Component	Central obesity		High TG		Low HDL		High BP		High BG	
	AUC	<i>P</i>	AUC	<i>P</i>	AUC	<i>P</i>	AUC	<i>P</i>	AUC	<i>P</i>
	(95%CI)		(95%CI)		(95%CI)		(95%CI)		(95%CI)	
BMI	0.83 (0.75-0.92)	<0.001	0.56 (0.39-0.73)	0.563	0.64 (0.49-0.79)	0.145	0.68 (0.58-0.78)	<0.001	0.50 <sup>a</sup> (0.35-0.65)	0.997
WC	0.82 (0.74-0.91)	<0.001	0.50 (0.32-0.67)	0.955	0.64 (0.51-0.77)	0.142	0.70 (0.61-0.80)	<0.001	0.54 (0.40-0.68)	0.584
WHR	0.65 <sup>a</sup> (0.54-0.75)	0.021	0.39 (0.24-0.54)	0.257	0.64 (0.51-0.77)	0.145	0.60 <sup>a</sup> (0.50-0.70)	0.066	0.62 (0.49-0.76)	0.106
ABSI	0.47 <sup>a,b</sup> (0.36-0.59)	0.681	0.39 (0.21-0.57)	0.253	0.53 (0.35-0.71)	0.736	0.59 <sup>a</sup> (0.49-0.69)	0.082	0.61 (0.48-0.74)	0.157
AVI	0.84 (0.75-0.92)	<0.001	0.50 (0.32-0.68)	0.981	0.64 (0.50-0.77)	0.153	0.71 (0.62-0.80)	<0.001	0.54 (0.40-0.69)	0.590
BAI	0.70 <sup>a</sup> (0.59-0.82)	<0.001	0.58 (0.38-0.78)	0.429	0.58 (0.39-0.77)	0.413	0.61 (0.51-0.71)	0.036	0.50 (0.34-0.66)	0.990
BRI	0.77 (0.68-0.87)	<0.001	0.49 (0.31-0.67)	0.918	0.64 (0.50-0.79)	0.142	0.67 <sup>a</sup> (0.57-0.76)	0.002	0.54 (0.39-0.69)	0.609
CI	0.58 <sup>a</sup>	0.220	0.44	0.550	0.61	0.271	0.63 <sup>a</sup>	0.013	0.59	0.222

	(0.47-0.69)		(0.26-0.63)		(0.44-0.77)		(0.53-0.73)		(0.46-0.73)
	0.62 <sup>a</sup>		0.59		0.56		0.52 <sup>a</sup>		0.59
VAI	0.060		0.328		0.524		0.739		0.261
	(0.51-0.73)		(0.41-0.78)		(0.39-0.73)		(0.41-0.62)		(0.44-0.73)

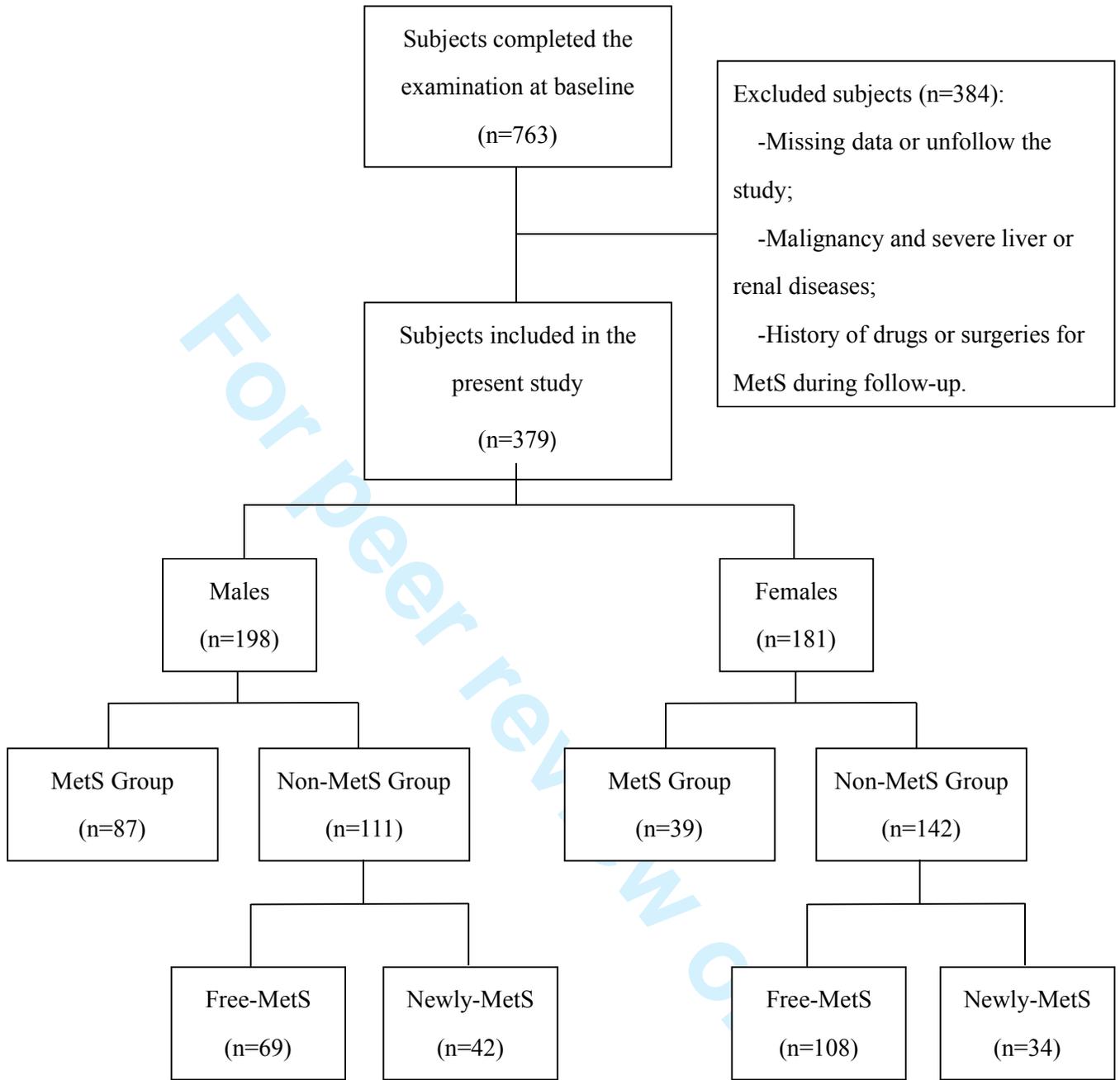
501 a, vs WC, *P*<0.05.

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**Supplement 1.** Morbidities of MetS and its components during follow-up.

	Male			Female			<i>P</i>
	Free, n	Newly, n	Morbidity, %	Free, n	Newly, n	Morbidity, %	
MetS	69	42	37.8	108	34	23.9	<b>0.017</b>
Central obesity	57	31	35.2	86	30	25.9	0.148
High TG	80	19	19.2	119	11	8.5	<b>0.017</b>
Low HDL	148	16	9.8	119	11	8.5	0.703
High BP	28	59	67.8	51	82	61.7	0.352
High BG	76	25	24.8	102	17	14.3	<b>0.049</b>

TG, triglyceride; HDL, high density lipoprotein cholesterol; BP, blood pressure; BG, blood glucose.

## STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Check
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	4
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	6-10
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-7
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	7-8
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7
Bias	9	Describe any efforts to address potential sources of bias	9-10
Study size	10	Explain how the study size was arrived at	6-7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9-10
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	9
		(b) Describe any methods used to examine subgroups and interactions	9
		(c) Explain how missing data were addressed	9-10
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed	6-7
		(e) <i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy (e) Describe any sensitivity analyses	NA

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<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10
		(b) Give reasons for non-participation at each stage	10
		(c) Consider use of a flow diagram	10
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10
		(b) Indicate number of participants with missing data for each variable of interest	10
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	10
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	10
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10-12
		(b) Report category boundaries when continuous variables were categorized	10-12
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	10-12
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10-12
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	13-15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-15
Generalisability	21	Discuss the generalisability (external validity) of the study results	13-15
<b>Other information</b>			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	16

\*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).

# BMJ Open

## Comparison of Anthropometric Indices for Predicting the Risk of Metabolic Syndrome and Its Components in Chinese Adults: A Prospective Study

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2017-016062.R1
Article Type:	Research
Date Submitted by the Author:	02-Jun-2017
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<b>&lt;b&gt;Primary Subject Heading&lt;/b&gt;:</b>	Diabetes and endocrinology
Secondary Subject Heading:	Diagnostics, Epidemiology
Keywords:	metabolic syndrome, waist circumference, abdominal volume index, visceral adiposity index, anthropometric index

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4 1 **Comparison of Anthropometric Indices for Predicting the Risk of**  
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6 2 **Metabolic Syndrome and Its Components in Chinese Adults: A**  
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8 3 **Prospective Study**

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4 455  
6 46 **Running title:** Anthropometric indices and Incident MetS7  
8 47  
910  
11 48 **Authors' statement:** The authors hereby confirm that neither the manuscript nor any part of it has  
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13 49 been published or is being considered for publication elsewhere. We acknowledge that all authors  
14  
15 50 participated sufficiently in the work and take public responsibility for its content.  
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21 52 **Funding:**22  
23  
24 53 1. the Chinese National Natural Science Foundation (Grant: 81300645)25  
26 54 2. the National Science and Technology Support Program (Grant: 2009BAI80B00)27  
28 55  
2930  
31 56 **Disclosure Summary:** The authors have no potential conflict of interest to declare.  
32  
3334 57  
3536 58 **Data Sharing Statement:** No additional data are available.  
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41 60 **Word count:** 317 (Abstract); 3233 (excluding abstract, figure captions, and references)42  
43 61  
4445  
46 62 **Figures & Tables:** 747  
48 63  
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64 **Abstract**

65 **Background:** Our study aimed to distinguish the ability of anthropometric indices to assess the risk of  
66 metabolic syndrome (MetS) during a 4.5-year follow-up.

67 **Setting, participants and outcome measures:** Data were collected from an epidemiological study  
68 between 2010 and 2014. At baseline, a total of 379 individuals (198 males and 181 females) aged  
69 from 40 to 65 were enrolled in the study. A variety of anthropometric parameters were measured and  
70 calculated, including waist circumference (WC), body mass index (BMI), a body shape index (ABSI),  
71 abdominal volume index (AVI), body adiposity index (BAI), body roundness index (BRI), conicity  
72 index (CI), waist-to-hip ratio (WHR) and visceral adiposity index (VAI). MetS was diagnosed  
73 according to the criteria of the International Diabetes Federation in 2009. Receiver Operating  
74 Characteristic (ROC) curve was applied to examine the potential of the above indices at baseline to  
75 identify the status and risk of MetS.

76 **Results:** At baseline, 43.9% of males and 21.5% of females suffered from MetS. All of the  
77 anthropometric indices showed clinical significance, and VAI was superior to the other indices, as it  
78 was found to have the largest area under the ROC curve at the time of cross-section analysis. After a  
79 4.5-year follow-up, 37.8% of males and 23.9% of females developed MetS. ROC curve analysis  
80 suggested that the strongest predictor of MetS was baseline BMI (0.77[0.68-0.85] and 0.71[0.63-0.78]  
81 for males and females, respectively) and AVI (0.76[0.67-0.84] and 0.72[0.64-0.79] for males and  
82 females, respectively). However, no significant difference was observed between WC and the both  
83 two indices. In contrast, the baseline ABSI did not predict MetS in both genders.

84 **Conclusions:** The present study indicated that these different indices derived from anthropometric  
85 parameters have different discriminatory abilities for MetS. Although WC did not have the largest

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4 86 area under the ROC curve for diagnosing and predicting MetS, it may remain the better index of  
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6 87 MetS status and risk because of its simplicity and wide utilization.  
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11 **Strengths and limitations of this study:**  
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14 90 1. This is a longitudinal prospective study of the association of anthropometric indices with  
15  
16 91 metabolic syndrome risk.  
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18 92 2. This is the first study to systematically report the different abilities of anthropometric indices in  
19  
20 93 diagnosing or predicting metabolic syndrome.  
21  
22 94 3. The object of the present study was middle-aged and elderly subjects in northeast China, limiting  
23  
24 95 the extension of the conclusion.  
25  
26 96 4. This study defined metabolic syndrome by IDF 2009 criterion. Therefore, further studies are  
27  
28 97 needed to determine whether the results are consistent under different criteria.  
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36 99 **Keywords**

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39 100 Metabolic syndrome; Waist circumference; Abdominal volume index; Visceral adiposity index;  
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41 101 Anthropometric index.  
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49 104 **Background**

50  
51 105 Metabolic syndrome (MetS), as a cluster of risk factors for cardiovascular morbidity and mortality<sup>1</sup>,  
52  
53 106 has become a major health concern in both developing and developed countries. It has been reported  
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55 107 that more a third of adults suffer from MetS by the National Health and Nutrition Examination  
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4 108 Survey<sup>2</sup>. A growing body of evidence supports the hypothesis that abdominal visceral fat plays a role  
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6 109 in the development of MetS<sup>3-6</sup>. Hence, it is reasonable that central obesity is defined as a predictor of  
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9 110 MetS.

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11 111 Body mass index (BMI) is widely used in assessing the obesity status<sup>7</sup>, but it cannot describe the  
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14 112 distribution of abdominal adipose tissue. Therefore, additional anthropometric indices are required to  
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16 113 assess abdominal adipose accumulation. Elevated waist circumference (WC) and waist-to-hip ratio  
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18 114 (WHR) were reported to be strongly associated with central obesity and MetS<sup>8</sup>. Moreover,  
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21 115 Krakauer's and Tomas' groups proposed a body shape index (ABSI) and body roundness index (BRI),  
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23  
24 116 respectively, to estimate body fat distribution. However, neither ABSI nor BRI have been proven a  
25  
26 117 more closely correlation with cardiovascular disease than BMI or WC<sup>9</sup>. Recently, Amato *et al.*,  
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29 118 reported an alternative anthropometric index, visceral adiposity index (VAI), that could be  
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31 119 considered as an indicator for cardiometabolic risk<sup>10</sup>. However, its advantages in predicting  
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34 120 metabolic diseases over other indices are still unclear. Abdominal volume index (AVI) is another  
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36 121 anthropometric tool for estimating overall volume. It was hold to have an extremely closely  
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39 122 relationship with the dysfunction of glucose metabolism<sup>11</sup>. Additionally, other indices have been  
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41 123 often used in epidemiologic research, such as conicity index (CI) and body adiposity index (BAI)<sup>12 13</sup>.  
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44 124 However, a comprehensive consensus has not been reached about the best indices for evaluating the  
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46 125 status and risk of MetS.

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49 126 Many studies suggest that different indicators differ in predicting disease occurrence

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51 127 Accumulating evidence has suggested that the different anthropometric indices differ in  
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54 128 determining MetS, but they are all cross-sectional. Thus, our study compared the ability in predicting  
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56 129 MetS of WC with other anthropometric indices including BMI, ABSI, AVI, BAI, BRI, CI, WHR, and  
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4 130 VAI aimed at explicating the prospective differences of various anthropometric indices.  
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## Methods

### 133 Study Population

134 To evaluate the effectiveness of anthropometric indices in predicting MetS, a community-based study  
135 involving 763 individuals was performed in 2010 in urban Shenyang, Liaoning Province, China. In  
136 2014, 472 of all the participants (61.9%) were underwent the follow-up. Exclusion criteria was as  
137 following: (1) subjects missing data or unfollow the study; (2) subjects with malignancy, hepatic  
138 dysfunction, or renal diseases; (3) subjects with history of drugs or surgeries for obesity,  
139 dyslipidemia, hypertension, or diabetes at baseline or during follow-up. Finally, data from 379  
140 participants (198 males and 181 females) aged 40-65 were selected for this study, and the average  
141 follow-up duration was 4.5 years (Figure 1).

142 This study was approved by the Ethics Committee of the First Affiliated Hospital of China  
143 Medical University, and all participants provided signed informed consent before enrollment in this  
144 study.

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### 146 Data Measurement and Collection

147 At baseline and at the endpoint, all subjects underwent comprehensive interviews and health  
148 examinations by trained staff. A questionnaire including demographic characteristics, personal  
149 medical history, and information related to the diagnosis and treatment of MetS was completed for  
150 each participant. Based on the previous standardized protocol<sup>14</sup>, body weight, height, waist  
151 circumference, hip circumference (HC), systolic blood pressure (SBP), and diastolic blood pressure

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4 152 (DBP) were measured. Participants were given a standard 75-g oral glucose tolerance test (OGTT).  
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6 153 Venous blood samples were drawn to determine fasting plasma glucose (FPG), plasma glucose 2  
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8 154 hours after a glucose load (2hPG), fasting plasma insulin (FINS), total cholesterol (TC), triglycerides  
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10 155 (TG), high-density lipoprotein cholesterol (HDL), and low-density lipoprotein cholesterol (LDL)  
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12 156 according to standard methods<sup>14 15</sup>.

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16 157 At baseline, all subjects had magnetic resonance imaging (MRI) scans performed at the abdominal  
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18 158 level between the 4<sup>th</sup> and 5<sup>th</sup> lumbar vertebrae in the prone position (FOV 42 cm×42 cm, thickness 1  
19  
20 159 cm, 6 layers, GE, USA). Subcutaneous fat area (SFA) and visceral fat area (VFA) were calculated  
21  
22 160 using SLICE-O-MATIC version4.2 software (Tomovision) by two separate technicians.  
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### 27 28 29 162 **Metabolic Syndrome Definition**

30  
31 163 The diagnose of MetS was based on the International Diabetes Federation criteria<sup>16</sup> in 2009 and  
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33 164 Chinese-specific abdominal obesity standard<sup>8</sup>, which means that the individual with any three or  
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35 165 more of the five following components can be considered MetS: (1) abdominal obesity (WC≥90 cm  
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37 166 for males, 85 cm for females); (2) elevated TG (TG≥1.70 mmol/L); (3) low HDL (HDL <1.0 mmol/L  
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39 167 for males, <1.3 for females) ; (4) high blood pressure (SBP≥130 mmHg, DBP≥85 mmHg, or a  
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41 168 history of hypertension) ; (5) elevated plasma glucose (FPG≥5.6 mmol/L, or a diagnosis of T2DM).  
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### 47 48 49 170 **Calculations**

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51 171 The homeostatic model assessment index for insulin resistance (HOMA-IR) was evaluated using the  
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53 172 formula:

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$$HOMA - IR = \frac{FPG(mmol/L) \times FINS(mIU/L)}{22.5}, \quad (mmol \times mIU/L^2).$$

174

175 The anthropometric indices, such as BMI, WHR, ABSI, AVI, BAI, BRI, CI, and VAI were calculated  
 176 using the following formulas<sup>10 17-20</sup>:

$$177 \text{ BMI} = \frac{\text{Weight}}{\text{Height}^2}, (\text{kg}^2/\text{m});$$

178

$$179 \text{ WHR} = \frac{\text{WC}}{\text{HC}};$$

$$180 \text{ ABSI} = \frac{\text{WC}}{\text{BMI}^{\frac{2}{3}} \times \text{Height}^{\frac{1}{2}}}, (\text{m}^{7/6}/\text{kg}^{2/3});$$

181

$$182 \text{ AVI} = \frac{2 \times \text{WC}^2 + 0.7 \times (\text{WC} - \text{HC})^2}{1000}, (\text{cm}^2)$$

183

$$184 \text{ BAI} = \frac{\text{HC}}{\text{Height}^{\frac{3}{2}}} - 18, (0.01\text{m}^{-1/2});$$

185

$$186 \text{ BRI} = 364.2 - 365.5 \times \sqrt{1 - \frac{(\text{WC}/2\pi)^2}{(0.5 \times \text{Height})^2}};$$

187

$$188 \text{ CI} = \frac{\text{WC}}{0.109 \times \sqrt{\frac{\text{Weight}}{\text{Height}}}}, (\text{m}^{2/3}/\text{kg}^{1/2});$$

189

$$190 \text{ VAI}_{\text{male}} = \left( \frac{\text{WC}}{39.68} - 1.88 \times \text{BMI} \right) \times \frac{\text{TG}}{1.03} \times \frac{1.31}{\text{HDL}};$$

191

$$192 \text{ VAI}_{\text{female}} = \left( \frac{\text{WC}}{36.58} - 1.89 \times \text{BMI} \right) \times \frac{\text{TG}}{0.81} \times \frac{1.52}{\text{HDL}};$$

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## 194 Statistical Analyses

195 Based on the diagnosis of MetS, the subjects were assigned to MetS group and non-MetS group at

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4 196 baseline. During follow-up, subjects in non-MetS group were further divided into newly MetS group  
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6 197 and free-MetS group according to whether or not they developed MetS.  
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9 198 The data distribution was assessed using the Kolmogorov-Smirnov test. The variables were  
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11 199 displayed as the mean±standard deviations, medians (interquartile range) or counts (percentages)  
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13 200 according to their types. Univariate analyses were conducted to estimate the relative factors of MetS  
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15 201 and its components using the *t*-test, Mann-Whitney rank sum test, Pearson's Chi-squared test, or  
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17 202 Fisher's exact test depending on the characteristics of the data. Area under receiver operating  
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19 203 characteristic (ROC) curves were calculated to evaluate the abilities of the anthropometric indices to  
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21 204 identify MetS. And new cutoff points were suggested by Youden's Index (sensitivity+specificity-1).  
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23 205 The ability of each anthropometric index to predict MetS was showed as areas under the ROC curves  
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25 206 and the confidence intervals. DeLong. Delong. Clarke-Pearson's nonparametric approach was used  
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27 207 to compare the areas under the ROC curves (AUCs)<sup>21</sup>. Statistical analyses were performed using  
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29 208 SPSS (version 23.0, IBM Corp., USA). MedCalc (version 16.2, MedCalc Software, Belgium) was  
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31 209 used to analyze the ROC curves. Statistical significance was defined as  $P < 0.05$  for all analyses.  
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## 41 211 Results

### 42 212 Baseline characteristics of the participants

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46 213 After 4.5 years, 472 of all the participants (61.9%) follow-up. According to the criteria mentioned  
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48 214 above, 198 males and 181 females were included in the present study. At baseline, 87 (43.9%) males  
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50 215 and 39 (21.5%) females were diagnosed as MetS. The median age of study subjects was 49.5  
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52 216 (45.0-55.0) years for males and 47.0 (44.0-54.0) years for females. Compared with the non-MetS  
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55 217 group, subjects with MetS had significantly higher levels of SBP, DBP, FPG, 2hPG, FINS, HbA1c,  
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4 218 TG, LDL, HOMA-IR, SFA, and VFA, but lower levels of HDL. TC was significantly increased in  
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6 219 males with MetS, while no significant difference was observed in females between MetS and  
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9 220 non-MetS. Furthermore, all of the nine anthropometric indices, including WC, BMI, WHR, ABSI,  
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11 221 AVI, BAI, BRI, CI, and VAI of the MetS group, were elevated significantly in both males and  
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14 222 females (**Table 1**).

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16 223 In the non-MetS group, 42 (37.8%) males and 34 (23.9%) females developed MetS after 4.5-years  
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18 224 follow-up. Compared with the healthy controls, TG, SFA, and VFA were significantly elevated in the  
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21 225 newly MetS group. Furthermore, females in the newly MetS group had higher levels of SBP, DBP,  
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24 226 2hPG, and LDL but lower levels of HDL at baseline. As for anthropometric indices, WC, BMI, WHR,  
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26 227 AVI, BRI, CI, and VAI of the newly MetS group were higher in both males and females. Baseline  
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29 228 BAI was increased in newly-MetS group for females, while no significant difference was observed  
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31 229 between free-MetS and newly MetS in males. Additionally, ABSI did not show significant difference  
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34 230 between the free-MetS and newly MetS groups in both males and females (**Table 2**).

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### 37 38 39 232 **Comparison of the anthropometric indices for diagnosing MetS at baseline**

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41 233 At baseline, the AUCs of all the anthropometric indices were larger than 0.5 ( $P < 0.05$ ), suggesting  
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43 234 their diagnostic significance for MetS (**Table 3**). Our results showed that the VAI had the largest  
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46 235 AUC for both genders (0.85 [0.79-0.92] for males and 0.90 [0.84-0.96] for females). The BAI (0.67  
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49 236 [0.59-0.75]) and ABSI (0.62 [0.52-0.72]) showed the lowest AUCs for males and females,  
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51  
52 237 respectively. In males, AVI, BRI, CI, and VAI had approximately the same AUCs as WC for  
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54 238 diagnosing MetS (all  $P > 0.05$  vs. WC). However, the AUCs of BMI, WHR, ABSI, and BAI were  
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56 239 significantly lower compared with WC for males (all  $P < 0.05$  vs. WC). In females, the AUC of VAI

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4 240 was significantly larger than WC, while the AUCs of ABSI, BAI, and CI were significantly lower (all  
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6 241  $P < 0.05$  vs. WC). The other four anthropometric indices showed no significant difference with WC in  
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9 242 diagnosing MetS for females (all  $P > 0.05$  vs. WC).

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#### 244 **Comparison of the anthropometric indices for predicting MetS during follow-up**

16 245 In general, the AUCs varied from 0.58 (0.49-0.68) for ABSI to 0.77 (0.68-0.85) for BMI in males  
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18 246 and from 0.55 (0.47-0.64) for ABSI to 0.72 (0.64-0.79) for AVI in females. The AUC of ABSI was  
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21 247 the lowest and did not differ from 0.5 in both males and females ( $P > 0.05$ ). Moreover, the AUC of  
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24 248 BAI was significantly larger than 0.5 in males, while no difference from 0.5 was observed in females.  
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26 249 All the AUCs of the other indices were greater than 0.5 ( $P < 0.05$ ), suggesting their clinical predictive  
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29 250 significance for MetS. In males, BMI had the largest AUC, but did not differ significantly from WC.  
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31 251 WHR, AVI, and BRI showed no significant difference with WC. Furthermore, ABSI, BAI, CI and  
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34 252 VAI had significantly lower AUCs than WC. In females, no significant difference was observed  
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36 253 between WC and BMI, WHR, AVI, BAI, BRI, CI, or VAI. Moreover, ABSI had a significantly lower  
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39 254 AUC than WC.

41 255 Other details of all the anthropometric indices such as cutoff, sensitivity, specificity, Youden index,  
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43 256 positive predictive value (PPV), and negative predictive value (NPV) were also reported in this study  
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46 257 **(Table 4)**.

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#### 51 259 **AUCs of the anthropometric indices for predicting MetS components during follow-up**

54 260 Compared with females, the morbidities of MetS, high TG and high blood glucose (BG) in males  
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56 261 were elevated (37.8% vs. 23.9%, 19.2% vs. 8.5%, and 24.8% vs. 14.3%, respectively) after a

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4 262 4.5-year follow-up. Morbidities of the other two MetS components showed no differences between  
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6 263 males and females (**Table S1**). Furthermore, we made comparisons of all indices in predicting MetS  
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8 264 components (**Table 5** and **Table 6**). Firstly, the AUCs of BMI, WHR, AVI, and BRI had predictive  
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10 265 significances for central obesity in males, while ABSI, BAI, CI, and VAI did not. However, in  
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12 266 females, the AUCs of ABSI, CI and VAI were not significantly larger than 0.5. In both genders, AVI  
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14 267 had the largest AUC for incident central obesity, but did not differed significantly from WC. Second,  
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16 268 BMI and VAI showed significances for predicting high TG in males. However, no significantly  
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18 269 predictive value was observed in the remaining indicators for males or females. Moreover, the AUCs  
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20 270 of all the indices were small for predicting low HDL and high BG, and none were significantly over  
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22 271 0.5. Therefore, none of the indices could discriminate among both males and females with low HDL  
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24 272 or high BG. Lastly, either BAI or VAI had an AUC less than 0.5 for high blood pressure (BP) in  
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26 273 males, and the AUCs of WHR, ABSI, and VAI were significantly less than 0.5 in females.  
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28 274 Furthermore, WC and AVI had the largest AUCs for high BP in males, and no difference was  
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30 275 observed between these two indices. In females, the AUC of AVI was the largest for high BP in  
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32 276 females but did not differ significantly from WC.  
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## 278 Discussion

279 There is abundant evidence that abdominal obesity is one of the most important risk factors of  
280 metabolic diseases such as diabetes mellitus and dyslipidemia<sup>8 22</sup>. The abdominal visceral fat area  
281 measured by MRI is still considered the best index to evaluate the extent of abdominal obesity<sup>23</sup>. Our  
282 results showed that incident MetS patients had a higher baseline visceral fat area compared with  
283 non-MetS patients, confirming that abdominal visceral fat can be an excellent indicator for MetS.

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4 284 However, considering the cost, safety and many other factors, it is not realistic to carry out  
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6 285 abdominal fat screen by MRI in clinic. Therefore, accumulating studies have conducted to find a  
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9 286 more simple and noninvasive approach to describe abdominal obesity. For a long time, a variety of  
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11 287 investigations have evaluated the ability of indices derived from several anthropometric parameters  
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14 288 in determining MetS. Most of these studies were cross-sectional. In this study, we compared nine  
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16 289 obesity indices, including WC, BMI, WHR, ABSI, AVI, BAI, BRI, CI, and VAI, in assessing the  
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19 290 incident risk of MetS using a 4.5-year prospective analysis. Our study indicated that some novel  
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21 291 anthropometric indices may be insufficient for evaluating the incident risk of MetS.

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24 292 At baseline, all the indices showed significant roles in diagnosing MetS, and VAI had the highest  
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26 293 AUC value in both males and females. For the calculation of the VAI value involving WC, BMI, TG,  
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28  
29 294 and HDL, it is suggested that VAI might provide a broader evaluation of metabolic risk related to  
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31 295 visceral fat dysfunction. Previous studies had reported that VAI has significant advantages over WC  
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34 296 for determining cardiometabolic risk<sup>10 24 25</sup>, even though a study in young adult indicated that VAI  
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36 297 did not provide a better efficiency of visceral adiposity assessment than WC and BMI<sup>26</sup>. In our study,  
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39 298 VAI was the best surrogate marker of MetS, especially considering the significant, excessive AUC in  
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41 299 females.

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44 300 Furthermore, we compared the AUCs of all the anthropometric indices for predicting MetS and its  
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46 301 components. In general, ABSI did not show predictive value for MetS in both genders. Previously, it  
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49 302 was reported to be a weak indicator for MetS in a few cross-sectional studies<sup>27 28</sup>. This finding was  
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51 303 confirmed by our prospective evidence. Furthermore, what was different from the cross-sectional  
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54 304 results is that the AUC of VAI was less than WC and even had a significant difference in males. In  
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56 305 2014, Chen *et al.* reported that the predictive performance of VAI is similar to WC for all-cause

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4 306 mortality<sup>25</sup>, suggesting that VAI as a predictor of MetS is not superior WC. Additionally, BMI and  
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6 307 AVI showed the strongest ability in the prediction of MetS for males and females, respectively.  
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9 308 However, neither BMI nor AVI had any significant difference from WC. In particular, considering  
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11 309 the simplicity and widespread utilization of WC, it appeared to be a more useful predictor of MetS in  
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14 310 clinical practice.

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16 311 Our study also proposed optimal cutoff points for these anthropometric indices. An obvious  
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18 312 difference between two genders was observed in WC, WHR, ABSI, BAI and VAI, suggesting that  
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21 313 gender-specific reference values should be used in clinical practice. Notably, the present results  
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24 314 showed that the optimal cutoff point for WC are considerably different from the cutoff point  
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26 315 according to the guideline on prevention and treatment of metabolic dysfunction in Chinese adults<sup>29</sup>.  
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29 316 Therefore, it may be optimal that the decreased WC cutoff is used in the clinical setting to select  
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31 317 Chinese adults at high risk of incident MetS. Additionally, all the PPVs of indices were less than  
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34 318 NPVs, suggesting that the indices covered in this article were suitable for excluding the risk for MetS  
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36 319 in a non-MetS population.

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39 320 Our study further finds that the indices show different discriminatory power for different MetS  
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41 321 components. AVI had the largest AUC for central obesity in both males and females. On the other  
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44 322 hand, VAI of males had the highest AUC value for high TG and high BP. In females, the AUC of AVI  
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46 323 for high BP was larger than the other indices, while no indicator showed significance in predicting  
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49 324 high TG. Interestingly, the CI played only a predictive role of new-onset high BP in both genders,  
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51 325 suggesting its worse predictive ability for MetS components. Some scholars believed that this is  
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54 326 probably because weight dilutes the influence of height according to its formula<sup>30</sup>. Additionally, all  
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56 327 the indices failed in forecasting incident low HDL and high BG, in contrast to other studies<sup>9 10 24 31</sup>.

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4 328 One possible explanation is that only a few individuals developed low HDL and high BG, and the  
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6 329 small sample size may impact on the reliability of results. In summary, the results above suggest that  
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9 330 the current indicators of anthropometric indices cannot provide a comprehensive prediction of  
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11 331 metabolic risk factors. Accordingly, further study to clarify the association of anthropometric  
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14 332 parameters with MetS components is necessary.

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16 333 Several limitations of the present study should be considered. First, this study was limited to  
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18 334 middle-aged and elderly subjects in northeast China. Hence, the applicability of these results may be  
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21 335 limited for other populations. Second, only the baseline anthropometric parameters were analyzed in  
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24 336 the study. For our study aims to assess the predictive abilities of anthropometric indices at baseline in  
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26 337 a prospective cohort, it is likely that the anthropometric changes during follow-up period had little  
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29 338 effect on the current results. Finally, IDF 2009 criterion was used in the present study to defined  
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31 339 metabolic syndrome. Therefore, further studies are needed to determine whether the results are  
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34 340 consistent under different criteria.

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### 37 38 39 342 **Conclusions**

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41 343 In conclusion, VAI is the best index for diagnosis of MetS. Moreover, BMI and AVI are superior to  
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43 344 the other anthropometric indices for predicting MetS in males and females, respectively, but no  
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46 345 obvious difference were observed between them and WC. Hence, considering the simplicity and  
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49 346 wide utilization, WC remains the more practical discriminator for MetS.

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### 52 53 54 348 **Abbreviations**

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56 349 MetS: metabolic syndrome; WC: waist circumference; BMI: body mass index; ABSI: a body shape

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4 350 index; AVI: abdominal volume index; BAI: body adiposity index; BRI, body roundness index; CI,  
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6 351 conicity index; WHR: waist-to-hip ratio; VAI: visceral adiposity index; ROC: Receiver operating  
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8 352 characteristic; AUC: areas under the ROC curve; HC: hip circumference; SBP: systolic blood  
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10 353 pressure; DBP: diastolic blood pressure; OGTT: 75g oral glucose tolerance test; FPG: fasting plasma  
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12 354 glucose; 2hPG: plasma glucose 2 hours after a glucose load; FINS: fasting plasma insulin; TC: total  
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14 355 cholesterol; TG: triglycerides; HDL: high-density lipoprotein cholesterol; LDL: low-density  
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16 356 lipoprotein cholesterol; MRI: magnetic resonance imaging; SFA: subcutaneous fat area; VFA:  
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18 357 visceral fat area; HOMA-IR: the homeostatic model assessment index for insulin resistance; PPV:  
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20 358 positive predictive value; NPV: negative predictive value; BG: blood glucose; BP: blood pressure.  
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### 360 **Declarations**

### 361 **Acknowledgements**

362 We thank the participants and staff at the Institute of Endocrinology of the First Affiliated Hospital of  
363 China Medical University for their involvement in this study.  
364

### 365 **Contributors**

366 Haoyu Wang was the primary investigator, and reviewed the literatures, performed this follow-up  
367 project, collected data, analyzed results, and produced the first draft of manuscript; Aihua Liu  
368 reviewed the literature, interpreted the data, and edited the manuscript; Tong Zhao, Xun Gong,  
369 Tianxiaopang, Yingying Zhou, Yue Xiao, Yumeng Yan, and Chenlin Fan participated in this  
370 follow-up project, collected and interpreted data; Weiping Teng supervised the statistical analyses,  
371 and edited the manuscript; Yaxin Lai and Zhongyan Shan supervised the statistical analyses, and

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4 372 produced the final version of the manuscript. All authors read and approved the final manuscript.  
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9 374 **Funding**

10  
11 375 This work was supported by the Chinese National Natural Science Foundation (Grant: 81300645)  
12  
13 376 and the National Science and Technology Support Program (Grant: 2009BAI80B00). The funders  
14  
15 377 had no roles in the study design, data collection or analysis, or the presentation or publication of the  
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17 378 results.  
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24 380 **Competing interests**

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26 381 The authors declare that they have no competing interests.  
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31 383 **Ethics approval**

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34 384 This study was approved by the Ethics Committee of the First Affiliated Hospital of China Medical  
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36 385 University. Informed consent was obtained from all individual participants included in the study.  
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41 387 **References**

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**Figure Caption**

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6 477 **Figure 1.** Flow graph of individual recruitment.  
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## Tables

480 **Table 1.** Baseline characteristics of study subjects according to the MetS status at baseline.

Characteristics	Male (n=198)			Female (n=181)		
	non-MetS	MetS	<i>P</i>	non-MetS	MetS	<i>P</i>
N (%)	111 (56.1)	87 (43.9)		142 (78.5)	39 (21.5)	
Age (yr)	49.0 (44.0-55.0)	50.0 (46.0-56.0)	0.397	47.5 (43.0-54.0)	47.0 (46.0-56.0)	0.515
SBP (mmHg)	123.3 (117.3-131.3)	136.7 (125.3-146.7)	<0.001	116.7 (108.7-123.7)	134.0 (120.0-148.0)	<0.001
DBP (mmHg)	80.0 (85.3-73.3)	87.3 (83.3-94.0)	<0.001	76.3 (69.3-80.2)	88.7 (92.7-80.0)	<0.001
FPG (mmol/L)	5.3 (5.0-5.7)	6.1 (5.4-7.2)	<0.001	5.3 (5.0-5.5)	5.8 (5.2-7.8)	<0.001
2hPG (mmol/L)	6.3 (5.2-7.5)	9.3 (6.8-12.3)	<0.001	6.8 (5.9-7.9)	9.6 (7.8-12.6)	<0.001
FINS (mIU/L)	12.49 (9.24-17.75)	16.77 (12.87-24.63)	<0.001	15.54 (12.50-19.69)	25.05 (18.65-30.54)	<0.001
HbA1c (%)	5.7 (5.4-6.0)	6.0 (5.6-6.7)	<0.001	5.9 (5.5-6.2)	6.2 (5.7-7.2)	0.005
TC (mmol/L)	4.8 (4.3-5.3)	5.3 (4.7-5.9)	0.001	5.1 (4.5-5.5)	5.2 (4.4-5.9)	0.494
TG (mmol/L)	1.3 (0.9-1.6)	2.4 (2.0-3.6)	<0.001	1.1 (0.9-1.5)	2.4 (1.7-3.8)	<0.001
HDL (mmol/L)	1.3 (1.1-1.5)	1.1 (0.9-1.3)	<0.001	1.5 (1.3-1.8)	1.1 (1.0-1.4)	<0.001
LDL (mmol/L)	3.0 (2.6-3.5)	3.1 (2.7-3.8)	0.148	3.1 (2.6-3.6)	3.2 (2.6-3.6)	0.963
HOMA-IR	2.98 (2.23-4.46)	4.74 (3.69-6.72)	<0.001	3.79 (2.81-4.86)	6.83 (4.17-8.30)	<0.001
Current Smoking, n (%)	75(67.57)	51(58.62)	0.194	7(4.93)	1(2.56)	0.844
Alcohol Intake, n (%)	39(35.14)	41(47.13)	0.088	3(2.11)	1(2.56)	1.000
SFA (cm <sup>2</sup> )	124.62±49.88	151.84±51.80	0.001	178.86±65.82	226.87±69.24	<0.001
VFA (cm <sup>2</sup> )	84.40±45.85	116.39±44.40	<0.001	57.76±24.16	91.80±32.98	<0.001

WC (cm)	87.3±8.1	94.7±7.9	<0.001	80.3±8.6	89.0±7.9	<0.001
BMI (kg/m <sup>2</sup> )	24.6±2.8	26.6±2.8	<0.001	23.9±3.0	27.1±3.4	<0.001
WHR	0.90±0.05	0.94±0.05	<0.001	0.85±0.06	0.90±0.05	<0.001
ABSI (m <sup>7/6</sup> /kg <sup>2/3</sup> )	0.0792±0.0033	0.0814±0.0034	<0.001	0.0770±0.0041	0.0784±0.0036	0.040
AVI (cm <sup>2</sup> )	15.24 (13.48-17.03)	17.86 (16.31-20.10)	<0.001	13.10 (11.56-14.30)	15.51 (14.62-17.79)	<0.001
BAI (0.01m <sup>-0.5</sup> )	25.84±3.01	27.33±2.68	<0.001	29.30±3.18	31.70±3.22	<0.001
BRI	3.65±0.95	4.49±0.98	<0.001	3.50±0.96	4.63±1.03	<0.001
CI (m <sup>2/3</sup> /kg <sup>1/2</sup> )	1.24±0.06	1.29±0.06	<0.001	1.20±0.07	1.25±0.06	<0.001
VAI	1.30 (0.94-1.84)	3.24 (2.17-4.63)	<0.001	1.43 (0.96-1.96)	4.30 (2.46-6.35)	<0.001

481 Abbreviations: SBP, systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose; 2hPG, 2 hours after  
 482 glucose-load plasma glucose; FINS, fasting plasma insulin; TC, total cholesterol; TG, triglycerides; HDL, high density lipoprotein  
 483 cholesterol; LDL, low density lipoprotein cholesterol; SFA, subcutaneous fat area; VFA, visceral fat area; BMI, body mass index;  
 484 WHR, waist-to-hip ratio; ABSI, a body shape index; AVI, abdominal volume index; BAI, body adiposity index; BRI, body roundness  
 485 index; CI, conicity; VAI, visceral adiposity index.

486 Data was presented in the form of mean±standard deviation, median (interquartile range) or counts (percentages), depending on its  
 487 type. All adiposity and cardiometabolic risk factors between groups with and without MetS were compared using an independent *t*-test,  
 488 Mann-Whitney rank sum test, Pearson's Chi-squared test, or Fisher's exact test according to the characteristics of the data.

489

490 **Table 2.** Baseline characteristics of healthy subjects who developed MetS or not at follow-up.

Characteristics	Male (n=111)			Female (n=142)		
	free-MetS	newly-MetS	<i>P</i>	free-MetS	newly-MetS	<i>P</i>
N (%)	69 (62.2)	42 (37.8)		108 (76.1)	34 (23.9)	
Age (yr)	49.0 (45.0-55.5)	50.5 (41.8-55.0)	0.549	47.0 (44.0-53.0)	48.5 (42.0-56.3)	0.754
SBP (mmHg)	122.0 (114.3-132.7)	125.0 (119.3-130.7)	0.239	113.3 (105.3-122.7)	120.0 (116.5-126.8)	0.003
DBP (mmHg)	80.0 (71.7-85.7)	80.0 (77.2-85.7)	0.314	74.7 (68.0-80.0)	79.0 (76.0-82.0)	< 0.001
FPG (mmol/L)	5.3 (4.9-5.6)	5.4 (5.1-5.9)	0.149	5.3 (5.0-5.5)	5.3 (5.0-5.6)	0.274
2hPG (mmol/L)	6.2 (5.3-7.5)	6.3 (5.1-8.4)	0.584	6.6 (5.8-7.6)	7.9 (6.9-9.5)	< 0.001
FINS (mIU/L)	12.18 (8.85-16.46)	12.60 (9.92-20.42)	0.341	15.32 (12.02-19.81)	16.15 (13.33-19.38)	0.374
HbA1c (%)	5.6 (5.4-5.8)	5.7 (5.4-6.2)	0.131	5.8 (5.5-6.1)	6.1 (5.6-6.3)	0.062
TC (mmol/L)	4.7 (4.3-5.3)	4.9 (4.3-5.5)	0.302	5.1 (4.5-5.5)	5.1 (4.6-5.9)	0.426
TG (mmol/L)	1.2 (0.9-1.6)	1.4 (1.1-1.7)	0.041	1.1 (0.8-1.5)	1.3 (1.0-1.7)	0.028
HDL (mmol/L)	1.3 (1.1-1.5)	1.2 (1.1-1.4)	0.075	1.6 (1.3-1.8)	1.5 (1.3-1.7)	0.029
LDL (mmol/L)	3.0±0.8	3.2±0.9	0.286	3.1±0.8	3.4±0.9	0.033
HOMA-IR	2.89 (2.20-3.92)	3.24 (2.25-4.91)	0.171	3.62 (2.75-4.78)	4.08 (3.13-5.07)	0.128
Current Smoking, n (%)	45 (65.22)	30 (71.43)	0.498	4 (3.70)	3 (8.82)	0.358
Alcohol Intake, n (%)	22 (31.88)	17 (40.48)	0.358	3 (2.78)	0 (0.00)	1.000
SFA (cm <sup>2</sup> )	110.19±44.09	149.19±50.11	< 0.001	169.42±61.17	207.78±71.90	0.003
VFA (cm <sup>2</sup> )	67.70±33.78	112.83±49.98	< 0.001	54.96±23.79	66.34±23.58	0.018
WC (cm)	84.5±7.5	91.9±6.9	< 0.001	78.9±8.3	84.7±8.1	< 0.001
BMI (kg/m <sup>2</sup> )	23.6±2.6	26.2±2.5	< 0.001	23.4±2.9	25.4±2.8	0.001
WHR	0.88±0.05	0.92±0.05	< 0.001	0.84±0.06	0.87±0.05	0.003

ABSI ( $m^{7/6}/kg^{2/3}$ )	0.0788±0.0030	0.0799±0.0036	0.090	0.0767±0.0038	0.0779±0.0047	0.119
AVI (cm <sup>2</sup> )	14.18(12.89-16.23)	16.21(15.13-18.57)	< 0.001	12.46(10.91-14.18)	13.95(13.31-15.89)	< 0.001
BAI (0.01m <sup>-0.5</sup> )	25.38±2.53	26.60±3.58	0.058	28.98±2.99	30.31±3.59	0.033
BRI	3.35±0.85	4.41±0.90	< 0.001	3.34±0.90	4.02±1.00	< 0.001
CI (m <sup>2/3</sup> /kg <sup>1/2</sup> )	1.22±0.06	1.26±0.06	0.001	1.19±0.06	1.22±0.07	0.007
VAI	1.17(0.84-1.70)	1.52(1.19-2.09)	0.009	1.35(0.86-1.83)	1.68(1.39-2.25)	0.004

491 Abbreviations: SBP, systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose; 2hPG, 2 hours after  
 492 glucose-load plasma glucose; FINS, fasting plasma insulin; TC, total cholesterol; TG, triglycerides; HDL, high density lipoprotein  
 493 cholesterol; LDL, low density lipoprotein cholesterol; SFA, subcutaneous fat area; VFA, visceral fat area; BMI, body mass index;  
 494 WHR, waist-to-hip ratio; ABSI, a body shape index; AVI, abdominal volume index; BAI, body adiposity index; BRI, body roundness  
 495 index; CI, conicity; VAI, visceral adiposity index.

496 Data was presented in the form of mean±standard deviation, median (interquartile range) or counts (percentages), depending on its  
 497 type. All adiposity and cardiometabolic risk factors between groups with and without MetS were compared using an independent *t*-test,  
 498 Mann-Whitney rank sum test, Pearson's Chi-squared test, or Fisher's exact test according to the characteristics of the data.

499

500 **Table 3.** AUCs of anthropometric indices in diagnosing of MetS at baseline.

Indices	Male			Female		
	AUC	95%CI	<i>P</i>	AUC	95%CI	<i>P</i>
WC	0.79	(0.72-0.86)	<0.001	0.79	(0.71-0.87)	<0.001
BMI	0.73 <sup>a</sup>	(0.65-0.80)	<0.001	0.75	(0.67-0.84)	<0.001
WHR	0.72 <sup>a</sup>	(0.64-0.79)	<0.001	0.75	(0.67-0.83)	<0.001
ABSI	0.70 <sup>a</sup>	(0.62-0.78)	<0.001	0.62 <sup>a</sup>	(0.52-0.72)	0.031
AVI	0.79	(0.72-0.86)	<0.001	0.79	(0.71-0.87)	<0.001
BAI	0.67 <sup>a</sup>	(0.59-0.75)	<0.001	0.69 <sup>a</sup>	(0.59-0.79)	<0.001
BRI	0.76	(0.69-0.83)	<0.001	0.80	(0.71-0.88)	<0.001
CI	0.76	(0.68-0.83)	<0.001	0.73 <sup>a</sup>	(0.64-0.82)	<0.001
VAI	0.85	(0.79-0.92)	<0.001	0.90 <sup>a</sup>	(0.84-0.96)	<0.001

501 Abbreviations: WC, waist circumference; BMI, body mass index; WHR, waist-to-hip ratio; ABSI, a body shape index; AVI, abdominal

502 volume index; BAI, body adiposity index; BRI, body roundness index; CI, conicity; VAI, visceral adiposity index.

503 DeLong. DeLong. Clarke-Pearson's nonparametric approach was used to compare the AUCs of indices.

504 a, compared with the AUC of waist circumference, *P* is less than 0.05

505 **Table 4.** AUCs, optimal cutoff, sensitivity, specificity, positive and negative predictive value for the anthropometric indices in ROC analysis for  
 506 predicting MetS.

Anthropometric Indices	AUC (95%CI)	<i>P</i>	Cut-off	Sensitivity	Specificity	Youden Index	PPV	NPV
Male								
WC	0.76 (0.67-0.84)	<0.001	84.0	0.95	0.54	0.49	0.56	0.95
BMI	0.77 (0.68-0.85)	<0.001	24.94	0.69	0.75	0.44	0.63	0.80
WHR	0.73 (0.64-0.81)	<0.001	0.89	0.76	0.64	0.40	0.56	0.81
ABSI	0.58 <sup>a</sup> (0.49-0.68)	0.149	0.0822	0.29	0.88	0.17	0.60	0.67
AVI	0.76 (0.67-0.84)	<0.001	14.25	0.95	0.54	0.49	0.56	0.95
BAI	0.59 <sup>a</sup> (0.49-0.68)	0.124	27.44	0.40	0.87	0.27	0.65	0.70
BRI	0.74 (0.65-0.82)	<0.001	3.47	0.81	0.58	0.39	0.54	0.83
CI	0.67 <sup>a</sup> (0.58-0.76)	<0.001	1.21	0.83	0.45	0.28	0.48	0.81
VAI	0.65 <sup>a</sup> (0.55-0.74)	0.005	1.06	0.83	0.48	0.31	0.49	0.82
Female								
WC	0.71 (0.64-0.79)	<0.001	80.0	0.82	0.60	0.42	0.39	0.91
BMI	0.71 (0.63-0.78)	<0.001	25.14	0.59	0.78	0.37	0.46	0.86
WHR	0.68 (0.59-0.75)	<0.001	0.81	0.91	0.37	0.28	0.31	0.93
ABSI	0.55 <sup>a</sup> (0.47-0.64)	0.358	0.0799	0.32	0.81	0.13	0.35	0.79

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AVI	0.72 (0.64-0.79)	<0.001	13.03	0.82	0.60	0.42	0.39	0.91
BAI	0.64 (0.56-0.72)	0.013	30.38	0.53	0.74	0.27	0.39	0.83
BRI	0.71 (0.63-0.79)	<0.001	3.58	0.71	0.66	0.37	0.40	0.88
CI	0.63 (0.54-0.71)	0.020	1.23	0.44	0.81	0.25	0.42	0.82
VAI	0.66 (0.58-0.74)	0.001	1.36	0.79	0.52	0.31	0.34	0.89

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507 Abbreviations: AUC, area under curve; PPV, positive predictive value; NPV, negative predictive value; WC, waist circumference; BMI, body mass index; WHR, waist-to-hip ratio; ABSI, a body  
508 shape index; AVI, abdominal volume index; BAI, body adiposity index; BRI, body roundness index; CI, conicity; VAI, visceral adiposity index.

509 DeLong. DeLong. Clarke-Pearson's nonparametric approach was used to compare the AUCs of indices.

510 a, compared with the AUC of waist circumference, P is less than 0.05

511

512 **Table 5.** Comparison of AUCs for anthropometric indices in predicting MetS components in males.

Component	Central obesity		High TG		Low HDL		High BP		High BG	
	AUC (95%CI)	<i>P</i>	AUC (95%CI)	<i>P</i>	AUC (95%CI)	<i>P</i>	AUC (95%CI)	<i>P</i>	AUC (95%CI)	<i>P</i>
WC	0.79 (0.69-0.89)	<0.001	0.63 (0.47-0.78)	0.118	0.45 (0.31-0.59)	0.523	0.77 (0.66-0.88)	<0.001	0.57 (0.43-0.70)	0.348
BMI	0.78 (0.67-0.89)	<0.001	0.69 (0.55-0.84)	0.016	0.53 (0.39-0.68)	0.675	0.72 (0.60-0.84)	<0.001	0.58 (0.45-0.71)	0.263
WHR	0.71 (0.59-0.83)	0.002	0.61 (0.46-0.76)	0.185	0.41 (0.26-0.57)	0.286	0.75 (0.64-0.86)	<0.001	0.59 (0.46-0.72)	0.199
ABSI	0.50 <sup>a</sup> (0.37-0.63)	0.996	0.47 (0.29-0.64)	0.665	0.37 (0.22-0.51)	0.104	0.72 (0.61-0.84)	<0.001	0.53 (0.38-0.68)	0.677
AVI	0.79 (0.69-0.89)	<0.001	0.62 (0.47-0.78)	0.123	0.45 (0.31-0.59)	0.555	0.77 (0.66-0.88)	<0.001	0.57 (0.43-0.70)	0.348
BAI	0.57 <sup>a</sup> (0.42-0.71)	0.340	0.60 (0.43-0.77)	0.217	0.56 (0.40-0.71)	0.502	0.63 <sup>a</sup> (0.51-0.75)	0.058	0.54 (0.40-0.68)	0.554
BRI	0.70 <sup>a</sup> (0.58-0.82)	0.004	0.65 (0.50-0.80)	0.060	0.48 (0.34-0.61)	0.776	0.75 (0.64-0.86)	<0.001	0.58 (0.45-0.72)	0.226
CI	0.60 <sup>a</sup>	0.139	0.54	0.604	0.39	0.181	0.76	<0.001	0.55	0.465

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	(0.48-0.73)		(0.37-0.71)		(0.25-0.53)		(0.65-0.87)		(0.41-0.69)
	0.58 <sup>a</sup>		0.69		0.61		0.61 <sup>a</sup>		0.56
VAI	0.266		0.016		0.179		0.113		0.365
	(0.45-0.70)		(0.57-0.82)		(0.45-0.77)		(0.48-0.74)		(0.43-0.70)

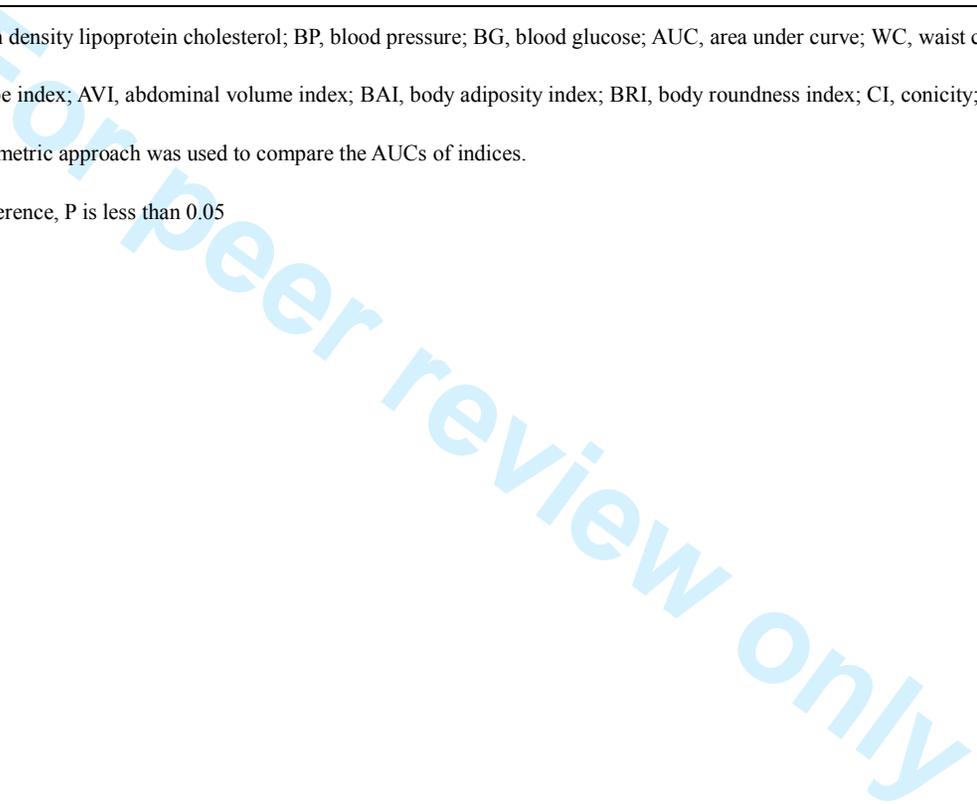
513 Abbreviations: TG, triglycerides; HDL, high density lipoprotein cholesterol; BP, blood pressure; BG, blood glucose; AUC, area under curve; WC, waist circumference; BMI, body mass index;

514 WHR, waist-to-hip ratio; ABSI, a body shape index; AVI, abdominal volume index; BAI, body adiposity index; BRI, body roundness index; CI, conicity; VAI, visceral adiposity index.

515 DeLong. DeLong. Clarke-Pearson's nonparametric approach was used to compare the AUCs of indices.

516 a, compared with the AUC of waist circumference, P is less than 0.05

517



518 **Table 6.** Comparison of AUCs for anthropometric indices in predicting MetS components in females.

Component	Central obesity		High TG		Low HDL		High BP		High BG	
	AUC	<i>P</i>	AUC	<i>P</i>	AUC	<i>P</i>	AUC	<i>P</i>	AUC	<i>P</i>
	(95%CI)		(95%CI)		(95%CI)		(95%CI)		(95%CI)	
BMI	0.83 (0.75-0.92)	<0.001	0.56 (0.39-0.73)	0.563	0.64 (0.49-0.79)	0.145	0.68 (0.58-0.78)	<0.001	0.50 <sup>a</sup> (0.35-0.65)	0.997
WC	0.82 (0.74-0.91)	<0.001	0.50 (0.32-0.67)	0.955	0.64 (0.51-0.77)	0.142	0.70 (0.61-0.80)	<0.001	0.54 (0.40-0.68)	0.584
WHR	0.65 <sup>a</sup> (0.54-0.75)	0.021	0.39 (0.24-0.54)	0.257	0.64 (0.51-0.77)	0.145	0.60 <sup>a</sup> (0.50-0.70)	0.066	0.62 (0.49-0.76)	0.106
ABSI	0.47 <sup>a</sup> (0.36-0.59)	0.681	0.39 (0.21-0.57)	0.253	0.53 (0.35-0.71)	0.736	0.59 <sup>a</sup> (0.49-0.69)	0.082	0.61 (0.48-0.74)	0.157
AVI	0.84 (0.75-0.92)	<0.001	0.50 (0.32-0.68)	0.981	0.64 (0.50-0.77)	0.153	0.71 (0.62-0.80)	<0.001	0.54 (0.40-0.69)	0.590
BAI	0.70 <sup>a</sup> (0.59-0.82)	<0.001	0.58 (0.38-0.78)	0.429	0.58 (0.39-0.77)	0.413	0.61 (0.51-0.71)	0.036	0.50 (0.34-0.66)	0.990
BRI	0.77 (0.68-0.87)	<0.001	0.49 (0.31-0.67)	0.918	0.64 (0.50-0.79)	0.142	0.67 <sup>a</sup> (0.57-0.76)	0.002	0.54 (0.39-0.69)	0.609
CI	0.58 <sup>a</sup>	0.220	0.44	0.550	0.61	0.271	0.63 <sup>a</sup>	0.013	0.59	0.222

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	(0.47-0.69)		(0.26-0.63)		(0.44-0.77)		(0.53-0.73)		(0.46-0.73)	
VAI	0.62 <sup>a</sup>	0.060	0.59	0.328	0.56	0.524	0.52 <sup>a</sup>	0.739	0.59	0.261
	(0.51-0.73)		(0.41-0.78)		(0.39-0.73)		(0.41-0.62)		(0.44-0.73)	

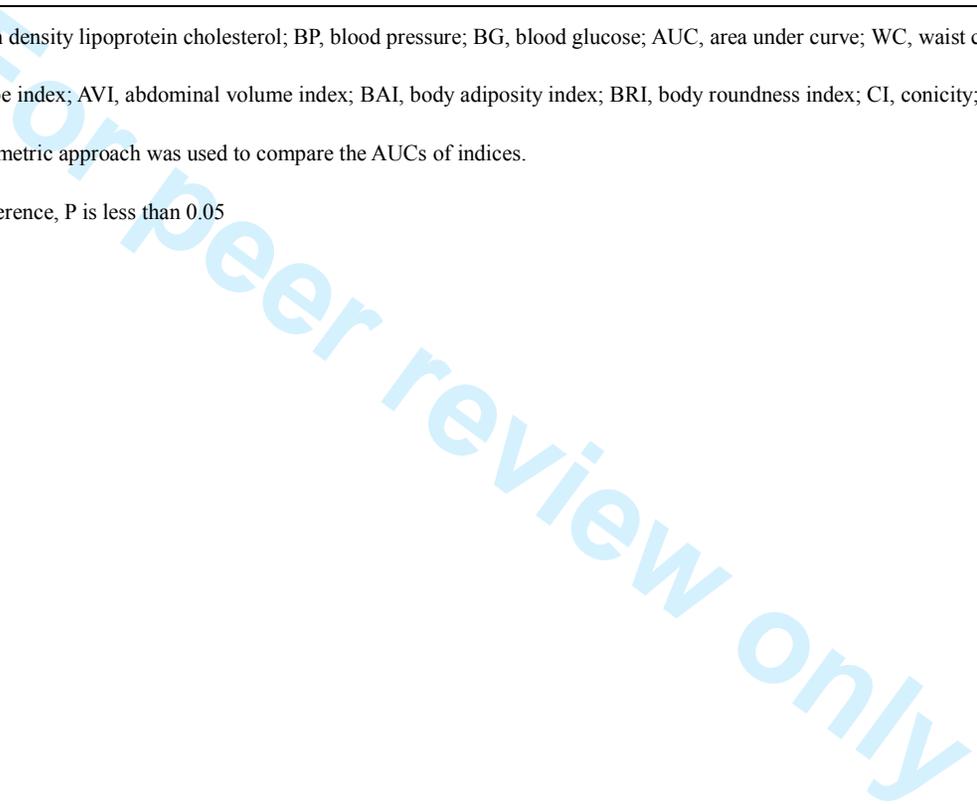
519 Abbreviations: TG, triglycerides; HDL, high density lipoprotein cholesterol; BP, blood pressure; BG, blood glucose; AUC, area under curve; WC, waist circumference; BMI, body mass index;

520 WHR, waist-to-hip ratio; ABSI, a body shape index; AVI, abdominal volume index; BAI, body adiposity index; BRI, body roundness index; CI, conicity; VAI, visceral adiposity index.

521 DeLong. DeLong. Clarke-Pearson's nonparametric approach was used to compare the AUCs of indices.

522 a, compared with the AUC of waist circumference, P is less than 0.05

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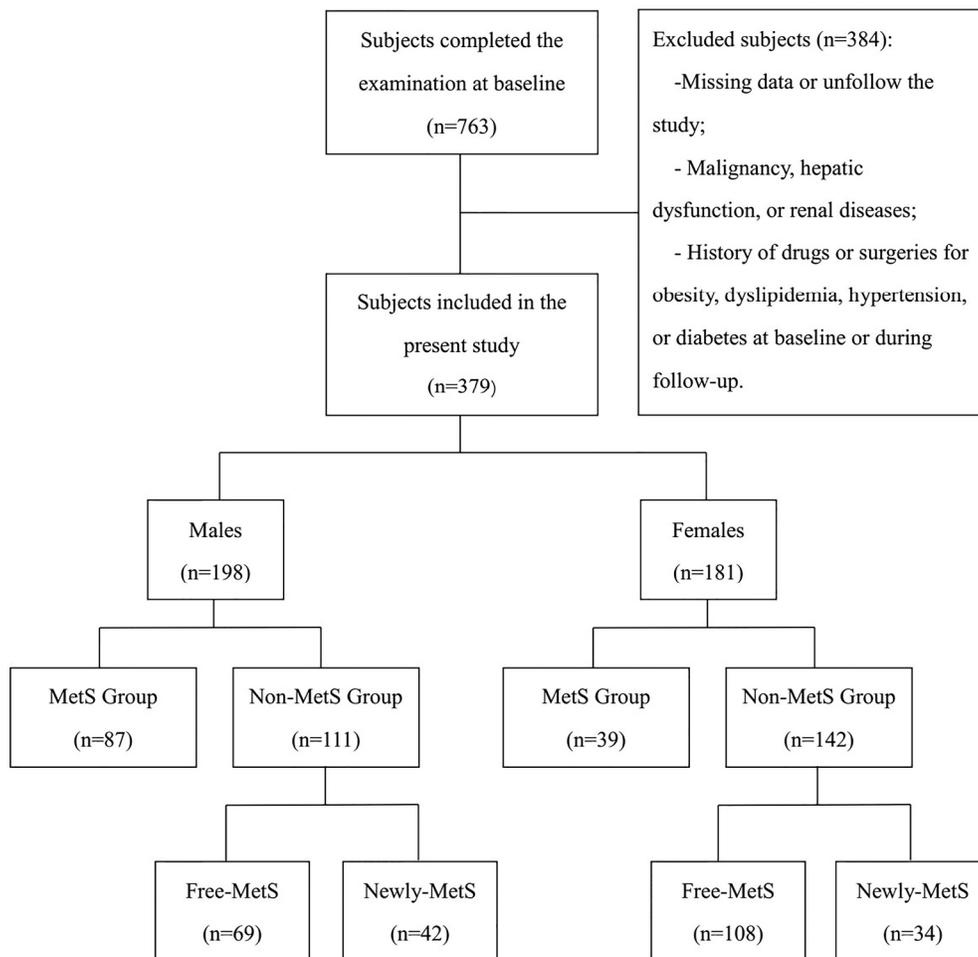


Figure 1. Flow graph of individual recruitment.

313x304mm (300 x 300 DPI)



**Supplement 1.** Morbidities of MetS and its components during follow-up.

	Male			Female			<i>P</i>
	Free, n	Newly, n	Morbidity, %	Free, n	Newly, n	Morbidity, %	
MetS	69	42	37.8	108	34	23.9	0.017
Central obesity	57	31	35.2	86	30	25.9	0.148
High TG	80	19	19.2	119	11	8.5	0.017
Low HDL	148	16	9.8	119	11	8.5	0.703
High BP	28	59	67.8	51	82	61.7	0.352
High BG	76	25	24.8	102	17	14.3	0.049

TG, triglyceride; HDL, high density lipoprotein cholesterol; BP, blood pressure; BG, blood glucose.

## STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Check
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1, 4-5
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	4-5
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	6-10
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-7
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	7-8
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	8
Bias	9	Describe any efforts to address potential sources of bias	9-10
Study size	10	Explain how the study size was arrived at	6-7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9-10
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	9-10
		(b) Describe any methods used to examine subgroups and interactions	10
		(c) Explain how missing data were addressed	7
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed <i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	7
		(e) Describe any sensitivity analyses	NA

Continued on next page

<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10
		(b) Give reasons for non-participation at each stage	10
		(c) Consider use of a flow diagram	10
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11
		(b) Indicate number of participants with missing data for each variable of interest	11
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	10
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	10
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11-13
		(b) Report category boundaries when continuous variables were categorized	11-13
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	11-13
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	11-13
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	13-16
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	13-16
<b>Other information</b>			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	17

\*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).

# BMJ Open

## Comparison of Anthropometric Indices for Predicting the Risk of Metabolic Syndrome and Its Components in Chinese Adults: A Prospective, Longitudinal Study

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2017-016062.R2
Article Type:	Research
Date Submitted by the Author:	24-Jul-2017
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<b>Primary Subject Heading</b> :	Diabetes and endocrinology
Secondary Subject Heading:	Diagnostics, Epidemiology
Keywords:	metabolic syndrome, waist circumference, abdominal volume index, visceral adiposity index, anthropometric index, body mass index

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4 1 **Comparison of Anthropometric Indices for Predicting the Risk of**  
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6 2 **Metabolic Syndrome and Its Components in Chinese Adults: A**  
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9 3 **Prospective, Longitudinal Study**

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**Running title:** Anthropometric indices and Incident MetS

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11 **Authors' statement:** The authors hereby confirm that neither the manuscript nor any part of it has  
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48 **Authors' statement:** The authors hereby confirm that neither the manuscript nor any part of it has  
49 been published or is being considered for publication elsewhere. We acknowledge that all authors  
50 participated sufficiently in the work and take public responsibility for its content.

**Funding:**

1. the Chinese National Natural Science Foundation (Grant: 81300645)
2. the National Science and Technology Support Program (Grant: 2009BAI80B00)

**Disclosure Summary:** The authors have no potential conflict of interest to declare.

**Data Sharing Statement:** No additional data are available.

**Word count:** 299 (Abstract); 3332 (excluding abstract, figure captions, and references)

**Figures & Tables:** 7

63

64 **Abstract**

65 **OBJECTIVES:** Our study aimed to distinguish the ability of anthropometric indices to assess the  
66 risk of metabolic syndrome (MetS).

67 **DESIGN:** Prospective cohort study.

68 **SETTING:** Shenyang, China.

69 **PARTICIPANTS:** A total of 379 residents aged between 40 and 65 were enrolled. 253 of them were  
70 free of MetS, and had been followed up for 4.5 years.

71 **METHODS:** At baseline, all the participants underwent a thorough medical examination. A variety  
72 of anthropometric parameters were measured and calculated, including waist circumference (WC),  
73 body mass index (BMI), a body shape index (ABSI), abdominal volume index (AVI), body adiposity  
74 index (BAI), body roundness index (BRI), conicity index (CI), waist-to-hip ratio (WHR) and visceral  
75 adiposity index (VAI). After 4.5-year follow-up, we re-examined whether participants were suffering  
76 from MetS. A receiver operating characteristic (ROC) curve was applied to examine the potential of  
77 the above indices to identify the status and risk of MetS.

78 **OUTCOMES:** Occurrence of MetS.

79 **RESULTS:** At baseline, 33.2% participants suffered from MetS. All of the anthropometric indices  
80 showed clinical significance, and VAI was superior to the other indices as it was found to have the  
81 largest area under the ROC curve. After a 4.5-year follow-up, 37.8% of males and 23.9% of females  
82 developed MetS. ROC curve analysis suggested that baseline BMI was the strongest predictor of  
83 MetS for males (0.77[0.68-0.85]), and AVI was the strongest for females(0.72[0.64-0.79]). However,  
84 no significant difference was observed between WC and both indices. In contrast, the baseline ABSI  
85 did not predict MetS in both genders.

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4 86 **CONCLUSIONS:** The present study indicated that these different indices derived from  
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6 87 anthropometric parameters have different discriminatory abilities for MetS. Although WC did not  
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9 88 have the largest area under the ROC curve for diagnosing and predicting MetS, it may remain a  
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11 89 better index of MetS status and risk because of its simplicity and wide utilization.  
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16 91 **Strengths and limitations of this study:**  
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19 92 1. This is the first study to systematically report different abilities of anthropometric indices in  
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21 93 diagnosing or predicting metabolic syndrome.  
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24 94 2. The prospective design is a strength of this study. Some previous reports have been limited by  
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26 95 their design (cross-sectional).  
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29 96 3. The participants in the present study were middle-aged and elderly in northeast China, which  
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31 97 limits the applicability of the conclusions to other populations.  
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34 98 4. This study defined metabolic syndrome using IDF 2009 criteria. Therefore, further studies are  
35  
36 99 needed to determine whether the results are consistent under different criteria.  
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42 **Keywords**

43  
44 102 Metabolic syndrome; Waist circumference; Abdominal volume index; Visceral adiposity index;

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46 103 Anthropometric index; Body mass index.  
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4 106 **Background**

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6 107 Metabolic syndrome (MetS), as a cluster of risk factors for cardiovascular morbidity and mortality<sup>1</sup>,  
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9 108 has become a major health concern in both developing and developed countries. It has been reported  
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11 109 that more than a third of adults suffer from MetS by the National Health and Nutrition Examination  
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13 110 Survey<sup>2</sup>. A growing body of evidence supports the hypothesis that abdominal visceral fat plays a role  
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15 111 in the development of MetS<sup>3-6</sup>. Hence, it is reasonable that central obesity is defined as a predictor of  
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19 112 MetS.

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21 113 Body mass index (BMI) is widely used in assessing the obesity status<sup>7</sup>, but it cannot describe the  
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23 114 distribution of abdominal adipose tissue. Therefore, additional anthropometric indices are required to  
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25 115 assess abdominal adipose accumulation. Elevated waist circumference (WC) and waist-to-hip ratio  
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28 116 (WHR) were reported to be strongly associated with central obesity and MetS<sup>8</sup>. Moreover,  
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30 117 Krakauer's and Tomas' groups proposed a body shape index (ABSI) and body roundness index (BRI),  
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32 118 respectively, to estimate body fat distributions. However, neither ABSI nor BRI have been shown to  
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34 119 be more closely correlated with cardiovascular disease than BMI or WC<sup>9</sup>. Recently, Amato *et al.*,  
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36 120 reported an alternative anthropometric index, i.e., visceral adiposity index (VAI), that could be  
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38 121 considered as an indicator for cardiometabolic risk<sup>10</sup>. However, its advantages in predicting  
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40 122 metabolic diseases over other indices are still unclear. The abdominal volume index (AVI) is another  
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42 123 anthropometric tool for estimating overall volume. It is thought to have an extremely close  
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44 124 relationship with the dysfunction of glucose metabolism<sup>11</sup>. Additionally, other indices have often  
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46 125 been used in epidemiologic research, such as the conicity index (CI) and body adiposity index  
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48 126 (BAI)<sup>12 13</sup>. However, a comprehensive consensus has not been reached about the best indices for  
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54 127 evaluating the status and risk of MetS.  
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4 128 Accumulating evidence has suggested that different anthropometric indices differ in determining  
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6 129 MetS, but they are all cross-sectional. Thus, our study compared the ability to predict MetS of WC  
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9 130 with other anthropometric indices including BMI, ABSI, AVI, BAI, BRI, CI, WHR and VAI to  
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11 131 explicate the prospective differences in various anthropometric indices.  
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## Methods

### 134 Study Population

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21 135 To evaluate the effectiveness of anthropometric indices in predicting MetS, a community-based  
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24 136 prospective cohort was established in 2010 in urban Shenyang, Liaoning Province, China. All 763  
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26 137 residents of the community aged between 40 and 65 were recruited. Exclusion criteria were as  
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29 138 follows: (1) participants with a history of drugs or surgeries for obesity, dyslipidaemia, hypertension,  
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31 139 or diabetes at baseline or during follow-up; (2) participants with malignancy, hepatic dysfunction, or  
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34 140 renal diseases. According to the above criteria, 379 participants were ultimately selected for this  
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36 141 study. At baseline, 253 of them (111 males and 142 females) did not suffer from MetS, and  
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39 142 underwent a 4.5-year follow-up (Figure 1).

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41 143 This study was approved by the Ethics Committee of the First Affiliated Hospital of China  
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44 144 Medical University, and all participants provided signed informed consent before enrolment in this  
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46 145 study.  
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### 147 Data Measurement and Collection

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54 148 At baseline and at the endpoint, all participants underwent comprehensive interviews and health  
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56 149 examinations by trained staff. A questionnaire, including demographic characteristics, personal  
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4 150 medical history, and information related to the diagnosis and treatment of MetS, was completed for  
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6 151 each participant. Based on the previous standardized protocol<sup>14</sup>, body weight, height, waist  
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8 152 circumference, hip circumference (HC), systolic blood pressure (SBP), and diastolic blood pressure  
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10 153 (DBP) were measured. Participants were given a standard 75-g oral glucose tolerance test (OGTT).  
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12 154 Venous blood samples were drawn to determine fasting plasma glucose (FPG), plasma glucose for 2  
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14 155 hours after a glucose load (2hPG), fasting plasma insulin (FINS), total cholesterol (TC), triglycerides  
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16 156 (TG), high-density lipoprotein cholesterol (HDL), and low-density lipoprotein cholesterol (LDL)  
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18 157 according to standard methods<sup>14 15</sup>.

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21 158 At baseline, all participants had magnetic resonance imaging (MRI) scans performed at the  
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23 159 abdominal level between the 4<sup>th</sup> and 5<sup>th</sup> lumbar vertebrae in the prone position (FOV 42 cm×42 cm,  
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25 160 thickness 1 cm, 6 layers, GE, USA). The subcutaneous fat area (SFA) and visceral fat area (VFA)  
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27 161 were calculated using SLICE-O-MATIC version 4.2 software (Tomovision) by two separate  
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29 162 technicians.  
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### 39 164 **Metabolic Syndrome Definition**

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41 165 The diagnosis of MetS was based on the International Diabetes Federation criteria<sup>16</sup> in 2009 and  
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43 166 Chinese-specific abdominal obesity standard<sup>8</sup>, which means that the individual with any three or  
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45 167 more of the five following components were considered to have MetS: (1) abdominal obesity (WC≥  
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47 168 90 cm for males, 85 cm for females); (2) elevated TG (TG≥1.70 mmol/L); (3) low HDL (HDL <1.0  
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49 169 mmol/L for males, <1.3 for females); (4) high blood pressure (SBP≥130 mmHg, DBP≥85 mmHg, or  
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51 170 a history of hypertension); and (5) elevated plasma glucose (FPG≥5.6 mmol/L, or a diagnosis of  
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6 173 **Calculations**

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9 174 The homeostatic model assessment index for insulin resistance (HOMA-IR) was evaluated using the  
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11 175 following formula:

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$$\text{HOMA-IR} = \text{FPG (mmol/L)} \times \text{FINS (mIU/L)} / 22.5$$

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16 177 The anthropometric indices, such as BMI, WHR, ABSI, AVI, BAI, BRI, CI, and VAI were calculated  
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18 178 using the following formulas<sup>10,17-20</sup>:

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$$\text{BMI} = \text{Weight (kg)} / \text{Height}^2 \text{ (m)};$$

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$$\text{WHR} = \text{WC (cm)} / \text{HC (cm)};$$

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$$\text{ABSI} = \text{WC (m)} / [\text{BMI}^{2/3} \text{ (kg/m}^2\text{)} \times \text{Height}^{1/2} \text{ (m)}];$$

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$$\text{AVI} = [2 \times \text{WC}^2 \text{ (cm)} + 0.7 \times (\text{WC} - \text{HC})^2 \text{ (cm)}] / 1000;$$

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$$\text{BAI} = [\text{HC (m)} / \text{Height}^{2/3} \text{ (m)}] - 18;$$

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$$\text{BRI} = 364.2 - 365.5 \times [1 - \pi^{-2} \times \text{WC}^2 \text{ (m)} \times \text{Height}^{-2} \text{ (m)}]^{1/2};$$

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$$\text{CI} = 0.109^{-1} \times \text{WC (m)} \times [\text{Weight (kg)} / \text{Height (m)}]^{-1/2};$$

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$$\text{VAI}_{\text{male}} = [\text{WC (cm)} / 39.68 - 1.88 \times \text{BMI (kg/m}^2\text{)}] \times [\text{TG (mmol/L)} / 1.03] \times [1.31 / \text{HDL (mmol/L)}];$$

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$$\text{VAI}_{\text{female}} = [\text{WC (cm)} / 36.58 - 1.89 \times \text{BMI (kg/m}^2\text{)}] \times [\text{TG (mmol/L)} / 0.81] \times [1.52 / \text{HDL (mmol/L)}];$$

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44 188 **Statistical Analyses**

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46 189 Based on the diagnosis of MetS, the participants were assigned to the MetS or non-MetS group at  
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49 190 baseline. During follow-up, participants in the non-MetS group were further divided into the  
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51 191 newly-MetS group and free-MetS group according to whether they developed MetS.

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54 192 The data distribution was assessed using the Kolmogorov-Smirnov test. The variables were  
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56 193 displayed as the mean  $\pm$  standard deviation, median (interquartile range) or count (percentage)

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4 194 according to their types. Univariate analyses were conducted to estimate the relative factors of MetS  
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6 195 and its components using a *t*-test, Mann-Whitney rank sum test, Pearson's Chi-squared test, or  
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9 196 Fisher's exact test depending on the characteristics of the data. The area under receiver operating  
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11 197 characteristic (ROC) curves was calculated to evaluate the abilities of the anthropometric indices to  
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14 198 identify MetS. New cut-off points were suggested by Youden's Index (sensitivity+specificity-1). The  
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16 199 ability of each anthropometric index to predict MetS was shown as areas under the ROC curves and  
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19 200 the confidence intervals. DeLong, Delong, and Clarke-Pearson's nonparametric approach was used  
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21 201 to compare the areas under the ROC curves (AUCs)<sup>21</sup>. Statistical analyses were performed using  
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24 202 SPSS (version 23.0, IBM Corp., USA). MedCalc (version 16.2, MedCalc Software, Belgium) was  
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26 203 used to analyse the ROC curves. Statistical significance was defined as  $P < 0.05$  for all analyses.  
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## Results

### Baseline characteristics of the participants

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36 207 According to the criteria mentioned above, 379 residents (198 males and 181 females) were included  
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38 208 in the present study. 253 of them were free of MetS, and received follow-up. According to the criteria  
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41 209 mentioned above, 198 males and 181 females were included in the present study. At baseline, 87  
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44 210 (43.9%) males and 39 (21.5%) females were diagnosed as having MetS. The median age of study  
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46 211 participants was 49.5 (45.0-55.0) years for males and 47.0 (44.0-54.0) years for females. Compared  
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49 212 with the non-MetS group, participants with MetS had significantly higher levels of SBP, DBP, FPG,  
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52 213 2hPG, FINS, HbA1c, TG, LDL, HOMA-IR, SFA, and VFA, but lower levels of HDL. TC was  
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54 214 significantly increased in males with MetS, while no significant difference was observed in females  
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57 215 between MetS and non-MetS. Furthermore, all of the nine anthropometric indices, including WC,

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4 216 BMI, WHR, ABSI, AVI, BAI, BRI, CI, and VAI, of the MetS group were elevated significantly in  
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6 217 both males and females (**Table 1**).

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8 218 In the non-MetS group, 42 (37.8%) males and 34 (23.9%) females developed MetS after the  
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10 219 4.5-year follow-up. Compared with the healthy controls, TG, SFA, and VFA were significantly  
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12 220 elevated in the newly-MetS group. Furthermore, females in the new MetS group had higher levels of  
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14 221 SBP, DBP, 2hPG, and LDL but lower levels of HDL at baseline. For anthropometric indices, WC,  
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16 222 BMI, WHR, AVI, BRI, CI, and VAI of the newly-MetS group were higher in both males and females.  
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18 223 Baseline BAI was increased in the newly-MetS group for females, while no significant difference  
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20 224 was observed between the free-MetS group and newly-MetS group in males. Additionally, ABSI did  
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22 225 not show a significant difference between the free-MetS and newly-MetS groups in both males and  
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24 226 females (**Table 2**).

### 25 26 27 28 29 30 31 32 33 34 228 **Comparison of the anthropometric indices for diagnosing MetS at baseline**

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36 229 At baseline, the AUCs of all the anthropometric indices were larger than 0.5 ( $P<0.05$ ), suggesting  
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38 230 their diagnostic significance for MetS (**Table 3**). Our results showed that the VAI had the largest  
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40 231 AUC for both genders (0.85 [0.79-0.92] for males and 0.90 [0.84-0.96] for females). The BAI (0.67  
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42 232 [0.59-0.75]) and ABSI (0.62 [0.52-0.72]) showed the lowest AUCs for males and females,  
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44 233 respectively. In males, AVI, BRI, CI, and VAI had approximately the same AUCs as WC for  
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46 234 diagnosing MetS (all  $P>0.05$  vs. WC). However, the AUCs of BMI, WHR, ABSI, and BAI were  
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48 235 significantly lower compared with WC for males (all  $P<0.05$  vs. WC). In females, the AUC of VAI  
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50 236 was significantly larger than WC, while the AUCs of ABSI, BAI, and CI were significantly lower (all  
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52 237  $P<0.05$  vs. WC). The other four anthropometric indices showed no significant differences with WC  
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4 238 in diagnosing MetS for females (all  $P>0.05$  vs. WC).  
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9 240 **Comparison of the anthropometric indices for predicting MetS during follow-up**

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11 241 In general, the AUCs varied from 0.58 (0.49-0.68) for ABSI to 0.77 (0.68-0.85) for BMI in males  
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13 242 and from 0.55 (0.47-0.64) for ABSI to 0.72 (0.64-0.79) for AVI in females. The AUC of ABSI was  
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15 243 the lowest and did not differ from 0.5 in both males and females ( $P>0.05$ ). Moreover, the AUC of  
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17 244 BAI was significantly larger than 0.5 in males, while no difference from 0.5 was observed in females.  
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19 245 All the AUCs of the other indices were greater than 0.5 ( $P<0.05$ ), suggesting their clinical predictive  
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21 246 significance for MetS. In males, BMI had the largest AUC but did not differ significantly from WC.  
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23 247 WHR, AVI, and BRI showed no significant difference with WC. Furthermore, ABSI, BAI, CI and  
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25 248 VAI had significantly lower AUCs than WC. In females, no significant difference was observed  
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27 249 between WC and BMI, WHR, AVI, BAI, BRI, CI, or VAI. Moreover, ABSI had a significantly lower  
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29 250 AUC than WC.  
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36 251 Other details of all the anthropometric indices such as cut-off, sensitivity, specificity, Youden  
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38 252 index, positive predictive value (PPV), and negative predictive value (NPV) were also reported in  
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40 253 this study (**Table 4**).  
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46 255 **AUCs of the anthropometric indices for predicting MetS components during follow-up**

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48 256 Compared with females, the morbidities of MetS, high TG and high blood glucose (BG) in males  
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50 257 were elevated (37.8% vs. 23.9%, 19.2% vs. 8.5%, and 24.8% vs. 14.3%, respectively) after a  
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52 258 4.5-year follow-up. Morbidities of the other two MetS components showed no differences between  
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54 259 males and females (**Table S1**). Furthermore, we made comparisons of all indices in predicting MetS  
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4 260 components (**Table 5** and **Table 6**). First, the AUCs of BMI, WHR, AVI, and BRI had predictive  
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6 261 significances for central obesity in males, while ABSI, BAI, CI, and VAI did not. However, in  
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8 262 females, the AUCs of ABSI, CI and VAI were not significantly larger than 0.5. In both genders, AVI  
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10 263 had the largest AUC for incident central obesity, but did not differ significantly from WC. Second,  
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12 264 BMI and VAI showed significances for predicting high TG in males. However, no significantly  
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14 265 predictive value was observed in the remaining indicators for males or females. Moreover, the AUCs  
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16 266 of all the indices were small for predicting low HDL and high BG, and none were significantly over  
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18 267 0.5. Therefore, none of the indices could discriminate among both males and females with low HDL  
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20 268 or high BG. Lastly, either BAI or VAI had an AUC less than 0.5 for high blood pressure (BP) in  
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22 269 males, and the AUCs of WHR, ABSI, and VAI were significantly less than 0.5 in females.  
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24 270 Furthermore, WC and AVI had the largest AUCs for high BP in males, and no difference was  
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26 271 observed between these two indices. In females, the AUC of AVI was the largest for high BP in  
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28 272 females but did not differ significantly from WC.  
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### 274 Discussion

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41 275 There is abundant evidence that abdominal obesity is one of the most important risk factors of  
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43 276 metabolic diseases such as diabetes mellitus and dyslipidaemia<sup>8 22</sup>. The abdominal visceral fat area  
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45 277 measured by MRI is still considered the best index to evaluate the extent of abdominal obesity<sup>23</sup>. Our  
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47 278 results showed that incident MetS patients had a higher baseline visceral fat area compared with  
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49 279 non-MetS patients, confirming that abdominal visceral fat can be an excellent indicator for MetS.  
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51 280 However, considering the cost, safety and many other factors, it is not realistic to carry out  
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53 281 abdominal fat screening with MRI in the clinic. Therefore, accumulating studies have been  
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4 282 conducted to find a more simple and non-invasive approach to describe abdominal obesity. For a  
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6 283 long time, a variety of investigations have evaluated the ability of indices derived from several  
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9 284 anthropometric parameters in determining MetS. Most of these studies were cross-sectional. In this  
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11 285 study, we compared nine obesity indices, including WC, BMI, WHR, ABSI, AVI, BAI, BRI, CI, and  
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13 286 VAI, in assessing the incident risk of MetS using a 4.5-year prospective analysis. Our study indicated  
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16 287 that some novel anthropometric indices may be insufficient for evaluating the incident risk of MetS.

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19 288 At baseline, all the indices showed significant roles in diagnosing MetS, and VAI had the highest  
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21 289 AUC value in both males and females. For calculation of the VAI value involving WC, BMI, TG,  
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23 290 and HDL, it is suggested that VAI might provide a broader evaluation of metabolic risk related to  
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26 291 visceral fat dysfunction. Previous studies have reported that VAI has significant advantages over WC  
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29 292 for determining cardiometabolic risk<sup>10 24 25</sup>, even though a study in young adults indicated that VAI  
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31 293 did not provide better efficiency of visceral adiposity assessment than WC and BMI<sup>26</sup>. In our study,  
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33 294 VAI was the best surrogate marker of MetS, especially considering the significant, excessive AUC in  
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36 295 females.

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39 296 Furthermore, we compared the AUCs of all the anthropometric indices for predicting MetS and its  
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41 297 components. In general, ABSI did not show a predictive value for MetS in both genders. Previously,  
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43 298 ABSI was reported to be a weak indicator for MetS in a few cross-sectional studies<sup>27 28</sup>. This finding  
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46 299 was confirmed by our prospective evidence. Furthermore, what was different from the  
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49 300 cross-sectional results is that the AUC of VAI was less than WC and even had a significant difference  
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51 301 in males. In 2014, Chen *et al.* reported that the predictive performance of VAI is similar to WC for  
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53 302 all-cause mortality<sup>25</sup>, suggesting that VAI as a predictor of MetS is not superior to WC. Additionally,  
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56 303 BMI and AVI showed the strongest ability in the prediction of MetS for males and females,  
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4 304 respectively. However, neither BMI nor AVI had any significant difference from WC. In particular,  
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6 305 considering the simplicity and widespread utilization of WC, it appeared to be a more useful  
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9 306 predictor of MetS in clinical practice.

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11 307 Our study also proposed optimal cut-off points for these anthropometric indices. An obvious  
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13 308 difference between two genders was observed in WC, WHR, ABSI, BAI and VAI, suggesting that  
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15 309 gender-specific reference values should be used in clinical practice. Notably, the present results  
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17 310 showed that the optimal cut-off point for WC are considerably different from the cut-off point  
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19 311 according to the guidelines on the prevention and treatment of metabolic dysfunction in Chinese  
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21 312 adults<sup>29</sup>. Therefore, it may be optimal that the decreased WC cut-off is used in the clinical setting to  
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23 313 select Chinese adults at high risk of incident MetS. Additionally, all the PPVs of indices were less  
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25 314 than NPVs, suggesting that the indices covered in this article were suitable for excluding the  
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27 315 individuals with high risk for MetS from a non-MetS population.

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29 316 Our study further found that the indices show different discriminatory power for different MetS  
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31 317 components. AVI had the largest AUC for central obesity in both males and females. On the other  
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33 318 hand, the VAI of males had the highest AUC value for high TG and high BP. In females, the AUC of  
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35 319 AVI for high BP was larger than the other indices, while no indicator showed significance in  
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37 320 predicting high TG. Interestingly, the CI played only a predictive role for new-onset high BP in both  
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39 321 genders, suggesting its worse predictive ability for MetS components. Some scholars have suggested  
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41 322 that this is probably because weight dilutes the influence of height according to its formula<sup>30</sup>.  
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43 323 Additionally, all the indices failed in forecasting incident low HDL and high BG, in contrast to other  
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45 324 studies<sup>9 10 24 31</sup>. One possible explanation is that only a few individuals developed low HDL and high  
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47 325 BG, and the small sample size may impact on the reliability of results. In summary, the results above  
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4 326 suggest that the current indicators of anthropometric indices cannot provide a comprehensive  
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6 327 prediction of metabolic risk factors. Accordingly, further study to clarify the association of  
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9 328 anthropometric parameters with MetS components is necessary.

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11 329 Several limitations of the present study should be considered. First, this study was limited to  
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14 330 middle-aged and elderly participants in northeast China. Hence, the applicability of these results may  
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16 331 be limited for other populations. Second, only the baseline anthropometric parameters were analysed  
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18 332 in the study. For our study aims to assess the predictive abilities of anthropometric indices at baseline  
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21 333 in a prospective cohort, it is likely that the anthropometric changes during the follow-up period had  
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24 334 little effect on the current results. Finally, IDF 2009 criteria were used in the present study to define  
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26 335 metabolic syndrome. Therefore, further studies are needed to determine whether the results are  
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29 336 consistent under different criteria.

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### 32 33 34 338 **Conclusions**

35  
36 339 In conclusion, VAI is the best index for the diagnosis of MetS. Moreover, BMI and AVI are superior  
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39 340 to the other anthropometric indices for predicting MetS in males and females, respectively, but no  
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41 341 obvious differences were observed between them and WC. Hence, considering the simplicity and  
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44 342 wide utilization, WC remains the more practical discriminator for MetS.

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### 47 48 49 344 **Abbreviations**

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51 345 MetS: metabolic syndrome; WC: waist circumference; BMI: body mass index; ABSI: a body shape  
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54 346 index; AVI: abdominal volume index; BAI: body adiposity index; BRI, body roundness index; CI,  
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56 347 conicity index; WHR: waist-to-hip ratio; VAI: visceral adiposity index; ROC: Receiver operating

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4 348 characteristic; AUC: areas under the ROC curve; HC: hip circumference; SBP: systolic blood  
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6 349 pressure; DBP: diastolic blood pressure; OGTT: 75 g oral glucose tolerance test; FPG: fasting plasma  
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8 350 glucose; 2hPG: plasma glucose for 2 hours after a glucose load; FINS: fasting plasma insulin; TC:  
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10 351 total cholesterol; TG: triglycerides; HDL: high-density lipoprotein cholesterol; LDL: low-density  
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12 352 lipoprotein cholesterol; MRI: magnetic resonance imaging; SFA: subcutaneous fat area; VFA:  
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14 353 visceral fat area; HOMA-IR: the homeostatic model assessment index for insulin resistance; PPV:  
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16 354 positive predictive value; NPV: negative predictive value; BG: blood glucose; BP: blood pressure.  
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#### 22 23 24 356 **Declarations**

#### 25 26 357 **Acknowledgements**

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29 358 We thank the participants and staff at the Institute of Endocrinology of the First Affiliated Hospital of  
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31 359 China Medical University for their involvement in this study.  
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#### 34 360 35 36 361 **Contributors**

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38 362 Haoyu Wang was the primary investigator, and reviewed the literatures, performed the follow-up  
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40 363 project, collected data, analysed results, and produced the first draft of manuscript; Aihua Liu  
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42 364 reviewed the literature, interpreted the data, and edited the manuscript; Tong Zhao, Xun Gong,  
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44 365 Tianxiaopang, Yingying Zhou, Yue Xiao, Yumeng Yan, and Chenlin Fan participated in this  
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46 366 follow-up project, collected and interpreted data; Weiping Teng supervised the statistical analyses,  
47  
48 367 and edited the manuscript; Yaxin Lai and Zhongyan Shan supervised the statistical analyses, and  
49  
50 368 produced the final version of the manuscript. All authors read and approved the final manuscript.  
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4 370 **Funding**

5  
6 371 This work was supported by the Chinese National Natural Science Foundation (Grant: 81300645)  
7  
8  
9 372 and the National Science and Technology Support Program (Grant: 2009BAI80B00). The funders  
10  
11 373 had no roles in the study design, data collection or analysis, or the presentation or publication of the  
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13 374 results.

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19 376 **Competing interests**

20  
21 377 The authors declare that they have no competing interests.  
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26 379 **Ethics approval**

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29 380 This study was approved by the Ethics Committee of the First Affiliated Hospital of China Medical  
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31 381 University. Informed consent was obtained from all individual participants included in the study.  
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### Figure Caption

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32 466 **Figure 1.** Flow graph of individual recruitment.  
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## Tables

469 **Table 1.** Baseline characteristics of study subjects according to the MetS status at baseline.

Characteristics	Male (n=198)			Female (n=181)		
	non-MetS	MetS	<i>P</i>	non-MetS	MetS	<i>P</i>
N (%)	111 (56.1)	87 (43.9)		142 (78.5)	39 (21.5)	
Age (yr)	49.0 (44.0-55.0)	50.0 (46.0-56.0)	0.397	47.5 (43.0-54.0)	47.0 (46.0-56.0)	0.515
SBP (mmHg)	123.3 (117.3-131.3)	136.7 (125.3-146.7)	<0.001	116.7 (108.7-123.7)	134.0 (120.0-148.0)	<0.001
DBP (mmHg)	80.0 (85.3-73.3)	87.3 (83.3-94.0)	<0.001	76.3 (69.3-80.2)	88.7 (92.7-80.0)	<0.001
FPG (mmol/L)	5.3 (5.0-5.7)	6.1 (5.4-7.2)	<0.001	5.3 (5.0-5.5)	5.8 (5.2-7.8)	<0.001
2hPG (mmol/L)	6.3 (5.2-7.5)	9.3 (6.8-12.3)	<0.001	6.8 (5.9-7.9)	9.6 (7.8-12.6)	<0.001
FINS (mIU/L)	12.49 (9.24-17.75)	16.77 (12.87-24.63)	<0.001	15.54 (12.50-19.69)	25.05 (18.65-30.54)	<0.001
HbA1c (%)	5.7 (5.4-6.0)	6.0 (5.6-6.7)	<0.001	5.9 (5.5-6.2)	6.2 (5.7-7.2)	0.005
TC (mmol/L)	4.8 (4.3-5.3)	5.3 (4.7-5.9)	0.001	5.1 (4.5-5.5)	5.2 (4.4-5.9)	0.494
TG (mmol/L)	1.3 (0.9-1.6)	2.4 (2.0-3.6)	<0.001	1.1 (0.9-1.5)	2.4 (1.7-3.8)	<0.001
HDL (mmol/L)	1.3 (1.1-1.5)	1.1 (0.9-1.3)	<0.001	1.5 (1.3-1.8)	1.1 (1.0-1.4)	<0.001
LDL (mmol/L)	3.0 (2.6-3.5)	3.1 (2.7-3.8)	0.148	3.1 (2.6-3.6)	3.2 (2.6-3.6)	0.963
HOMA-IR	2.98 (2.23-4.46)	4.74 (3.69-6.72)	<0.001	3.79 (2.81-4.86)	6.83 (4.17-8.30)	<0.001
Current Smoking, n (%)	75(67.57)	51(58.62)	0.194	7(4.93)	1(2.56)	0.844
Alcohol Intake, n (%)	39(35.14)	41(47.13)	0.088	3(2.11)	1(2.56)	1.000
SFA (cm <sup>2</sup> )	124.62±49.88	151.84±51.80	0.001	178.86±65.82	226.87±69.24	<0.001
VFA (cm <sup>2</sup> )	84.40±45.85	116.39±44.40	<0.001	57.76±24.16	91.80±32.98	<0.001

WC (cm)	87.3±8.1	94.7±7.9	<0.001	80.3±8.6	89.0±7.9	<0.001
BMI (kg/m <sup>2</sup> )	24.6±2.8	26.6±2.8	<0.001	23.9±3.0	27.1±3.4	<0.001
WHR	0.90±0.05	0.94±0.05	<0.001	0.85±0.06	0.90±0.05	<0.001
ABSI (m <sup>7/6</sup> /kg <sup>2/3</sup> )	0.0792±0.0033	0.0814±0.0034	<0.001	0.0770±0.0041	0.0784±0.0036	0.040
AVI (cm <sup>2</sup> )	15.24 (13.48-17.03)	17.86 (16.31-20.10)	<0.001	13.10 (11.56-14.30)	15.51 (14.62-17.79)	<0.001
BAI (0.01m <sup>-0.5</sup> )	25.84±3.01	27.33±2.68	<0.001	29.30±3.18	31.70±3.22	<0.001
BRI	3.65±0.95	4.49±0.98	<0.001	3.50±0.96	4.63±1.03	<0.001
CI (m <sup>2/3</sup> /kg <sup>1/2</sup> )	1.24±0.06	1.29±0.06	<0.001	1.20±0.07	1.25±0.06	<0.001
VAI	1.30 (0.94-1.84)	3.24 (2.17-4.63)	<0.001	1.43 (0.96-1.96)	4.30 (2.46-6.35)	<0.001

470 Abbreviations: SBP, systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose; 2hPG, plasma glucose for 2  
 471 hours after a glucose load; FINS, fasting plasma insulin; TC, total cholesterol; TG, triglycerides; HDL, high density lipoprotein  
 472 cholesterol; LDL, low density lipoprotein cholesterol; SFA, subcutaneous fat area; VFA, visceral fat area; BMI, body mass index;  
 473 WHR, waist-to-hip ratio; ABSI, a body shape index; AVI, abdominal volume index; BAI, body adiposity index; BRI, body roundness  
 474 index; CI, conicity; VAI, visceral adiposity index.  
 475 Data was presented in the form of mean ± standard deviation, median (interquartile range) or counts (percentages), depending on its  
 476 type. All adiposity and cardiometabolic risk factors between groups with and without MetS were compared using an independent *t*-test,  
 477 Mann-Whitney rank sum test, Pearson's Chi-squared test, or Fisher's exact test according to the characteristics of the data.  
 478

479 **Table 2.** Baseline characteristics of healthy subjects who developed MetS or not at follow-up.

Characteristics	Male (n=111)			Female (n=142)		
	free-MetS	newly-MetS	<i>P</i>	free-MetS	newly-MetS	<i>P</i>
N (%)	69 (62.2)	42 (37.8)		108 (76.1)	34 (23.9)	
Age (yr)	49.0 (45.0-55.5)	50.5 (41.8-55.0)	0.549	47.0 (44.0-53.0)	48.5 (42.0-56.3)	0.754
SBP (mmHg)	122.0 (114.3-132.7)	125.0 (119.3-130.7)	0.239	113.3 (105.3-122.7)	120.0 (116.5-126.8)	0.003
DBP (mmHg)	80.0 (71.7-85.7)	80.0 (77.2-85.7)	0.314	74.7 (68.0-80.0)	79.0 (76.0-82.0)	< 0.001
FPG (mmol/L)	5.3 (4.9-5.6)	5.4 (5.1-5.9)	0.149	5.3 (5.0-5.5)	5.3 (5.0-5.6)	0.274
2hPG (mmol/L)	6.2 (5.3-7.5)	6.3 (5.1-8.4)	0.584	6.6 (5.8-7.6)	7.9 (6.9-9.5)	< 0.001
FINS (mIU/L)	12.18 (8.85-16.46)	12.60 (9.92-20.42)	0.341	15.32 (12.02-19.81)	16.15 (13.33-19.38)	0.374
HbA1c (%)	5.6 (5.4-5.8)	5.7 (5.4-6.2)	0.131	5.8 (5.5-6.1)	6.1 (5.6-6.3)	0.062
TC (mmol/L)	4.7 (4.3-5.3)	4.9 (4.3-5.5)	0.302	5.1 (4.5-5.5)	5.1 (4.6-5.9)	0.426
TG (mmol/L)	1.2 (0.9-1.6)	1.4 (1.1-1.7)	0.041	1.1 (0.8-1.5)	1.3 (1.0-1.7)	0.028
HDL (mmol/L)	1.3 (1.1-1.5)	1.2 (1.1-1.4)	0.075	1.6 (1.3-1.8)	1.5 (1.3-1.7)	0.029
LDL (mmol/L)	3.0±0.8	3.2±0.9	0.286	3.1±0.8	3.4±0.9	0.033
HOMA-IR	2.89 (2.20-3.92)	3.24 (2.25-4.91)	0.171	3.62 (2.75-4.78)	4.08 (3.13-5.07)	0.128
Current Smoking, n (%)	45 (65.22)	30 (71.43)	0.498	4 (3.70)	3 (8.82)	0.358
Alcohol Intake, n (%)	22 (31.88)	17 (40.48)	0.358	3 (2.78)	0 (0.00)	1.000
SFA (cm <sup>2</sup> )	110.19±44.09	149.19±50.11	< 0.001	169.42±61.17	207.78±71.90	0.003
VFA (cm <sup>2</sup> )	67.70±33.78	112.83±49.98	< 0.001	54.96±23.79	66.34±23.58	0.018
WC (cm)	84.5±7.5	91.9±6.9	< 0.001	78.9±8.3	84.7±8.1	< 0.001
BMI (kg/m <sup>2</sup> )	23.6±2.6	26.2±2.5	< 0.001	23.4±2.9	25.4±2.8	0.001
WHR	0.88±0.05	0.92±0.05	< 0.001	0.84±0.06	0.87±0.05	0.003

ABSI (m <sup>7/6</sup> /kg <sup>2/3</sup> )	0.0788±0.0030	0.0799±0.0036	0.090	0.0767±0.0038	0.0779±0.0047	0.119
AVI (cm <sup>2</sup> )	14.18(12.89-16.23)	16.21(15.13-18.57)	< 0.001	12.46(10.91-14.18)	13.95(13.31-15.89)	< 0.001
BAI (0.01m <sup>-0.5</sup> )	25.38±2.53	26.60±3.58	0.058	28.98±2.99	30.31±3.59	0.033
BRI	3.35±0.85	4.41±0.90	< 0.001	3.34±0.90	4.02±1.00	< 0.001
CI (m <sup>2/3</sup> /kg <sup>1/2</sup> )	1.22±0.06	1.26±0.06	0.001	1.19±0.06	1.22±0.07	0.007
VAI	1.17(0.84-1.70)	1.52(1.19-2.09)	0.009	1.35(0.86-1.83)	1.68(1.39-2.25)	0.004

480 Abbreviations: SBP, systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose; 2hPG, plasma glucose for 2  
 481 hours after a glucose load; FINS, fasting plasma insulin; TC, total cholesterol; TG, triglycerides; HDL, high density lipoprotein  
 482 cholesterol; LDL, low density lipoprotein cholesterol; SFA, subcutaneous fat area; VFA, visceral fat area; BMI, body mass index;  
 483 WHR, waist-to-hip ratio; ABSI, a body shape index; AVI, abdominal volume index; BAI, body adiposity index; BRI, body roundness  
 484 index; CI, conicity; VAI, visceral adiposity index.

485 Data was presented in the form of mean ± standard deviation, median (interquartile range) or counts (percentages), depending on its  
 486 type. All adiposity and cardiometabolic risk factors between groups with and without MetS were compared using an independent *t*-test,  
 487 Mann-Whitney rank sum test, Pearson's Chi-squared test, or Fisher's exact test according to the characteristics of the data.

488

489 **Table 3.** AUCs of anthropometric indices in diagnosing of MetS at baseline.

Indices	Male			Female		
	AUC	95%CI	<i>P</i>	AUC	95%CI	<i>P</i>
WC	0.79	(0.72-0.86)	<0.001	0.79	(0.71-0.87)	<0.001
BMI	0.73 <sup>a</sup>	(0.65-0.80)	<0.001	0.75	(0.67-0.84)	<0.001
WHR	0.72 <sup>a</sup>	(0.64-0.79)	<0.001	0.75	(0.67-0.83)	<0.001
ABSI	0.70 <sup>a</sup>	(0.62-0.78)	<0.001	0.62 <sup>a</sup>	(0.52-0.72)	0.031
AVI	0.79	(0.72-0.86)	<0.001	0.79	(0.71-0.87)	<0.001
BAI	0.67 <sup>a</sup>	(0.59-0.75)	<0.001	0.69 <sup>a</sup>	(0.59-0.79)	<0.001
BRI	0.76	(0.69-0.83)	<0.001	0.80	(0.71-0.88)	<0.001
CI	0.76	(0.68-0.83)	<0.001	0.73 <sup>a</sup>	(0.64-0.82)	<0.001
VAI	0.85	(0.79-0.92)	<0.001	0.90 <sup>a</sup>	(0.84-0.96)	<0.001

490 Abbreviations: WC, waist circumference; BMI, body mass index; WHR, waist-to-hip ratio; ABSI, a body shape index; AVI, abdominal

491 volume index; BAI, body adiposity index; BRI, body roundness index; CI, conicity; VAI, visceral adiposity index.

492 DeLong, Delong, Clarke-Pearson's nonparametric approach was used to compare the AUCs of indices.

493 a, compared with the AUC of waist circumference, *P* is less than 0.05

494 **Table 4.** AUCs, optimal cutoff, sensitivity, specificity, positive and negative predictive value for the anthropometric indices in ROC analysis for  
 495 predicting MetS.

Anthropometric Indices	AUC (95%CI)	<i>P</i>	Cut-off	Sensitivity	Specificity	Youden Index	PPV	NPV
Male								
WC	0.76 (0.67-0.84)	<0.001	84.0	0.95	0.54	0.49	0.56	0.95
BMI	0.77 (0.68-0.85)	<0.001	24.94	0.69	0.75	0.44	0.63	0.80
WHR	0.73 (0.64-0.81)	<0.001	0.89	0.76	0.64	0.40	0.56	0.81
ABSI	0.58 <sup>a</sup> (0.49-0.68)	0.149	0.0822	0.29	0.88	0.17	0.60	0.67
AVI	0.76 (0.67-0.84)	<0.001	14.25	0.95	0.54	0.49	0.56	0.95
BAI	0.59 <sup>a</sup> (0.49-0.68)	0.124	27.44	0.40	0.87	0.27	0.65	0.70
BRI	0.74 (0.65-0.82)	<0.001	3.47	0.81	0.58	0.39	0.54	0.83
CI	0.67 <sup>a</sup> (0.58-0.76)	<0.001	1.21	0.83	0.45	0.28	0.48	0.81
VAI	0.65 <sup>a</sup> (0.55-0.74)	0.005	1.06	0.83	0.48	0.31	0.49	0.82
Female								
WC	0.71 (0.64-0.79)	<0.001	80.0	0.82	0.60	0.42	0.39	0.91
BMI	0.71 (0.63-0.78)	<0.001	25.14	0.59	0.78	0.37	0.46	0.86
WHR	0.68 (0.59-0.75)	<0.001	0.81	0.91	0.37	0.28	0.31	0.93
ABSI	0.55 <sup>a</sup> (0.47-0.64)	0.358	0.0799	0.32	0.81	0.13	0.35	0.79

AVI	0.72 (0.64-0.79)	<0.001	13.03	0.82	0.60	0.42	0.39	0.91
BAI	0.64 (0.56-0.72)	0.013	30.38	0.53	0.74	0.27	0.39	0.83
BRI	0.71 (0.63-0.79)	<0.001	3.58	0.71	0.66	0.37	0.40	0.88
CI	0.63 (0.54-0.71)	0.020	1.23	0.44	0.81	0.25	0.42	0.82
VAI	0.66 (0.58-0.74)	0.001	1.36	0.79	0.52	0.31	0.34	0.89

496 Abbreviations: AUC, area under curve; PPV, positive predictive value; NPV, negative predictive value; WC, waist circumference; BMI, body mass index; WHR, waist-to-hip ratio; ABSI, a body

497 shape index; AVI, abdominal volume index; BAI, body adiposity index; BRI, body roundness index; CI, conicity; VAI, visceral adiposity index.

498 DeLong. DeLong. Clarke-Pearson's nonparametric approach was used to compare the AUCs of indices.

499 a, compared with the AUC of waist circumference, P is less than 0.05

500

501 **Table 5.** Comparison of AUCs for anthropometric indices in predicting MetS components in males.

Component	Central obesity		High TG		Low HDL		High BP		High BG	
	AUC	<i>P</i>	AUC	<i>P</i>	AUC	<i>P</i>	AUC	<i>P</i>	AUC	<i>P</i>
	(95%CI)		(95%CI)		(95%CI)		(95%CI)		(95%CI)	
WC	0.79 (0.69-0.89)	<0.001	0.63 (0.47-0.78)	0.118	0.45 (0.31-0.59)	0.523	0.77 (0.66-0.88)	<0.001	0.57 (0.43-0.70)	0.348
BMI	0.78 (0.67-0.89)	<0.001	0.69 (0.55-0.84)	0.016	0.53 (0.39-0.68)	0.675	0.72 (0.60-0.84)	<0.001	0.58 (0.45-0.71)	0.263
WHR	0.71 (0.59-0.83)	0.002	0.61 (0.46-0.76)	0.185	0.41 (0.26-0.57)	0.286	0.75 (0.64-0.86)	<0.001	0.59 (0.46-0.72)	0.199
ABSI	0.50 <sup>a</sup> (0.37-0.63)	0.996	0.47 (0.29-0.64)	0.665	0.37 (0.22-0.51)	0.104	0.72 (0.61-0.84)	<0.001	0.53 (0.38-0.68)	0.677
AVI	0.79 (0.69-0.89)	<0.001	0.62 (0.47-0.78)	0.123	0.45 (0.31-0.59)	0.555	0.77 (0.66-0.88)	<0.001	0.57 (0.43-0.70)	0.348
BAI	0.57 <sup>a</sup> (0.42-0.71)	0.340	0.60 (0.43-0.77)	0.217	0.56 (0.40-0.71)	0.502	0.63 <sup>a</sup> (0.51-0.75)	0.058	0.54 (0.40-0.68)	0.554
BRI	0.70 <sup>a</sup> (0.58-0.82)	0.004	0.65 (0.50-0.80)	0.060	0.48 (0.34-0.61)	0.776	0.75 (0.64-0.86)	<0.001	0.58 (0.45-0.72)	0.226
CI	0.60 <sup>a</sup>	0.139	0.54	0.604	0.39	0.181	0.76	<0.001	0.55	0.465

	(0.48-0.73)		(0.37-0.71)		(0.25-0.53)		(0.65-0.87)		(0.41-0.69)	
	0.58 <sup>a</sup>		0.69		0.61		0.61 <sup>a</sup>		0.56	
VAI	0.266		0.016		0.179		0.113		0.365	
	(0.45-0.70)		(0.57-0.82)		(0.45-0.77)		(0.48-0.74)		(0.43-0.70)	

502 Abbreviations: TG, triglycerides; HDL, high density lipoprotein cholesterol; BP, blood pressure; BG, blood glucose; AUC, area under curve; WC, waist circumference; BMI, body mass index;

503 WHR, waist-to-hip ratio; ABSI, a body shape index; AVI, abdominal volume index; BAI, body adiposity index; BRI, body roundness index; CI, conicity; VAI, visceral adiposity index.

504 DeLong. DeLong. Clarke-Pearson's nonparametric approach was used to compare the AUCs of indices.

505 a, compared with the AUC of waist circumference, P is less than 0.05

506

507 **Table 6.** Comparison of AUCs for anthropometric indices in predicting MetS components in females.

Component	Central obesity		High TG		Low HDL		High BP		High BG	
	AUC	<i>P</i>	AUC	<i>P</i>	AUC	<i>P</i>	AUC	<i>P</i>	AUC	<i>P</i>
	(95%CI)		(95%CI)		(95%CI)		(95%CI)		(95%CI)	
BMI	0.83 (0.75-0.92)	<0.001	0.56 (0.39-0.73)	0.563	0.64 (0.49-0.79)	0.145	0.68 (0.58-0.78)	<0.001	0.50 <sup>a</sup> (0.35-0.65)	0.997
WC	0.82 (0.74-0.91)	<0.001	0.50 (0.32-0.67)	0.955	0.64 (0.51-0.77)	0.142	0.70 (0.61-0.80)	<0.001	0.54 (0.40-0.68)	0.584
WHR	0.65 <sup>a</sup> (0.54-0.75)	0.021	0.39 (0.24-0.54)	0.257	0.64 (0.51-0.77)	0.145	0.60 <sup>a</sup> (0.50-0.70)	0.066	0.62 (0.49-0.76)	0.106
ABSI	0.47 <sup>a</sup> (0.36-0.59)	0.681	0.39 (0.21-0.57)	0.253	0.53 (0.35-0.71)	0.736	0.59 <sup>a</sup> (0.49-0.69)	0.082	0.61 (0.48-0.74)	0.157
AVI	0.84 (0.75-0.92)	<0.001	0.50 (0.32-0.68)	0.981	0.64 (0.50-0.77)	0.153	0.71 (0.62-0.80)	<0.001	0.54 (0.40-0.69)	0.590
BAI	0.70 <sup>a</sup> (0.59-0.82)	<0.001	0.58 (0.38-0.78)	0.429	0.58 (0.39-0.77)	0.413	0.61 (0.51-0.71)	0.036	0.50 (0.34-0.66)	0.990
BRI	0.77 (0.68-0.87)	<0.001	0.49 (0.31-0.67)	0.918	0.64 (0.50-0.79)	0.142	0.67 <sup>a</sup> (0.57-0.76)	0.002	0.54 (0.39-0.69)	0.609
CI	0.58 <sup>a</sup>	0.220	0.44	0.550	0.61	0.271	0.63 <sup>a</sup>	0.013	0.59	0.222

	(0.47-0.69)		(0.26-0.63)		(0.44-0.77)		(0.53-0.73)		(0.46-0.73)
	0.62 <sup>a</sup>		0.59		0.56		0.52 <sup>a</sup>		0.59
VAI	0.060		0.328		0.524		0.739		0.261
	(0.51-0.73)		(0.41-0.78)		(0.39-0.73)		(0.41-0.62)		(0.44-0.73)

508 Abbreviations: TG, triglycerides; HDL, high density lipoprotein cholesterol; BP, blood pressure; BG, blood glucose; AUC, area under curve; WC, waist circumference; BMI, body mass index;

509 WHR, waist-to-hip ratio; ABSI, a body shape index; AVI, abdominal volume index; BAI, body adiposity index; BRI, body roundness index; CI, conicity; VAI, visceral adiposity index.

510 DeLong, Delong, Clarke-Pearson's nonparametric approach was used to compare the AUCs of indices.

511 a, compared with the AUC of waist circumference, P is less than 0.05

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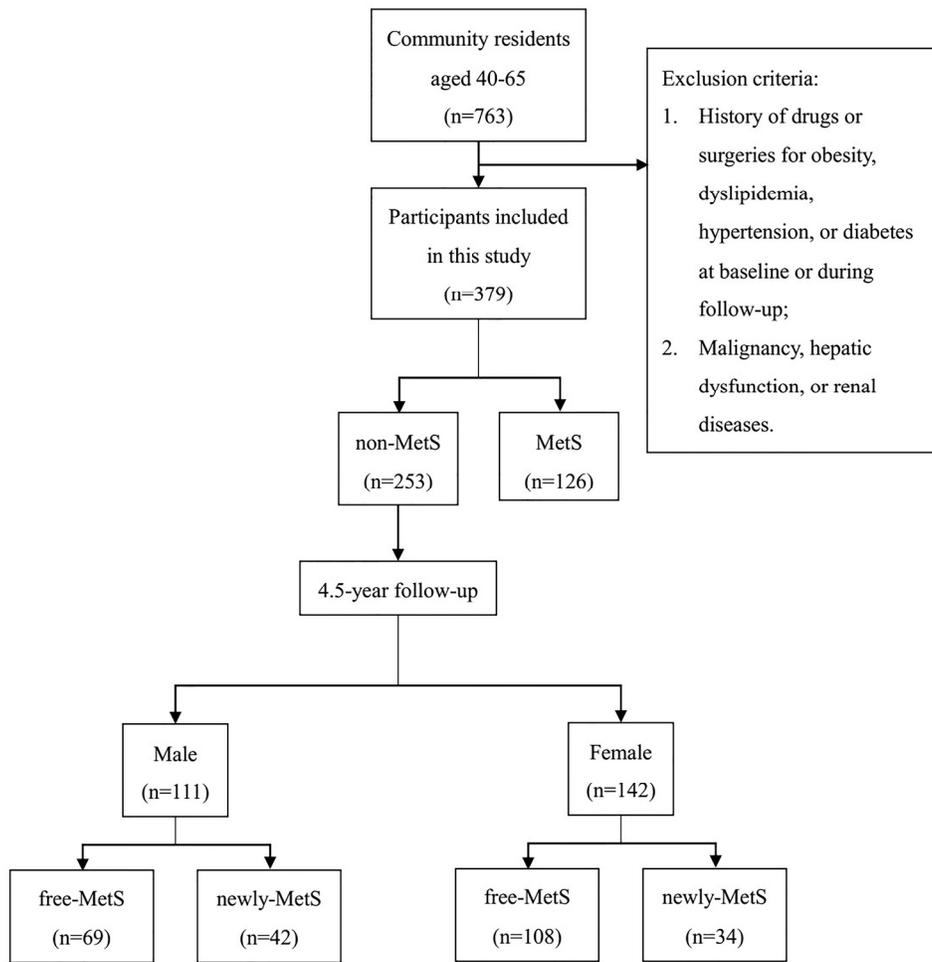


Figure 1. Flow graph of individual recruitment.

308x304mm (300 x 300 DPI)

**Supplement 1.** Morbidities of MetS and its components during follow-up.

	Male			Female			<i>P</i>
	Free, n	Newly, n	Morbidity, %	Free, n	Newly, n	Morbidity, %	
MetS	69	42	37.8	108	34	23.9	0.017
Central obesity	57	31	35.2	86	30	25.9	0.148
High TG	80	19	19.2	119	11	8.5	0.017
Low HDL	148	16	9.8	119	11	8.5	0.703
High BP	28	59	67.8	51	82	61.7	0.352
High BG	76	25	24.8	102	17	14.3	0.049

TG, triglyceride; HDL, high density lipoprotein cholesterol; BP, blood pressure; BG, blood glucose.

## STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Check
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1, 4
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	4-5
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6-7
Objectives	3	State specific objectives, including any prespecified hypotheses	7
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	7-10
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7-8
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	7-8
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-9
Bias	9	Describe any efforts to address potential sources of bias	9-10
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9-10
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	9-10
		(b) Describe any methods used to examine subgroups and interactions	9-10
		(c) Explain how missing data were addressed	7
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed	7
		(e) <i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy (e) Describe any sensitivity analyses	NA

Continued on next page

<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10
		(b) Give reasons for non-participation at each stage	10
		(c) Consider use of a flow diagram	10
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11
		(b) Indicate number of participants with missing data for each variable of interest	11
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	10
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	10
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11-13
		(b) Report category boundaries when continuous variables were categorized	11-13
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	11-13
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	11-13
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	13-16
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15-16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	15-16
<b>Other information</b>			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	17

\*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).