The visceral fat area to skeletal muscle mass ratio (VSR) is significantly associated with the risk of cardiometabolic diseases in a young and middle-aged Chinese natural population: a cross-sectional study

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Abstract

Background: Growing evidence has revealed that using BMI for assessment of obesity and cardiometabolic risk has some limitations. Visceral adiposity and skeletal muscle loss may be both correlated with cardiometabolic outcomes. This study aimed to explore the associations between the visceral fat area to skeletal muscle mass ratio (VSR) and the risk of several cardiometabolic diseases including metabolic associated fatty liver disease (MAFLD), hyperglycemia, hypertension, dyslipidemia and hyperuricemia in a young and middle-aged Chinese natural population and further elucidate the differences of these associations between male and female. Methods: A total of 5158 participants were included in this study. Body composition, anthropometrical and biochemical measurements were performed. The associations between VSR and cardiometabolic diseases were analyzed. Results: Both in male and female, VSR was positively associated with the five cardiometabolic diseases and with the increase of VSR by one quartile, the ORs increased significantly for all the five cardiometabolic diseases (P trend<0.001). With regard to the highest versus the lowest quartile of VSR, the ORs for MAFLD, hyperglycemia, hypertension, dyslipidemia and hyperuricemia were 17.23 (95% CI, 12.52-23.71), 15.47 (95% CI, 7.1-33.72), 5.12 (95% CI, 3.88-6.76), 3.16 (95% CI, 2.33-4.28) and 1.89 (95% CI, 1.42-2.51) in male, respectively. In female, the corresponding ORs were 41.15 (95% CI, 25.80-65.63), 21.62 (95% CI, 7.87-59.36), 9.64 (95% CI, 6.88-13.53), 9.34 (95% CI, 6.63-13.14) and 6.58 (95% CI, 3.45-12.56). The results of restricted cubic splines showed there were significant positive non-linear relationships between VSR and the risk of MAFLD, dyslipidemia, hyperglycemia and hypertension in both genders (P for non-linearity <0.05). The risk was relatively flat until when VSR reached 3.078 cm2/kg in men and 4.750 cm2/kg in women and started to increase rapidly afterwards. In men, however, the risk slowed down after VSR value got to around 4 cm2/kg and the curve became flat and even tended to decline. Conclusions: VSR was positively associated with cardiometabolic diseases regardless of gender. As VSR increased, the risk of cardiometabolic diseases was significantly higher in women than in men. Women should be more alert to the risk of cardiometabolic diseases caused by the increase of VSR.

Background

The prevalence of obesity is increasing dramatically worldwide in the past few decades. Obesity is well recognized as the most important risk factor for cardiometabolic diseases such as metabolic associated fatty liver disease (MAFLD), type 2 diabetes (T2DM), hypertension, dyslipidemia and hyperuricemia [1]. Obesity and its closely associated cardiometabolic disorders have placed a heavy burden on the public health system globally [2]. Since body mass index (BMI) is the most easily measured parameter of obesity, it is widely used for assessment of obesity in clinical practice. However, BMI fails to accurately distinguish between body fat mass and lean mass, and moreover, it can not describe the distribution of body fat. Mounting evidence suggests that visceral fat deposition is the main cause for the development of cardiometabolic diseases, whereas subcutaneous fat accumulation may be associated with decreased risk of the aforementioned cardiometabolic conditions [3]. Consequently, studies that do not take abdominal obesity into consideration and use BMI to define obesity have most commonly demonstrated the “obesity paradox” [4]. In addition to visceral adiposity, the impact of reduced skeletal muscle mass in the development of insulin resistance, T2DM and other cardiometabolic outcomes has become the focus of attention in recent years [5].

Visceral fat and skeletal muscle mass both play important roles in cardiometabolic risk, therefore they may have a synergistic effect on cardiometabolic disorders [6]. However, there are limited large-scale studies regarding their combined effect on cardiometabolic outcomes. What's more, it is generally recognized that there exists gender
difference in visceral fat distribution \cite{7}. Whether the joint effect of these two distinct compartments of body composition differs between different genders is unknown yet. Therefore, this study aimed to explore the association between the visceral fat area to skeletal muscle mass ratio (VSR) and the risk of several cardiometabolic diseases including MAFLD, hyperglycemia, hypertension, dyslipidemia and hyperuricemia in a Chinese population undergoing regular health checkup and further elucidate the difference of this association between men and women.

**Methods**

**Study population**

A total of 5158 participants who took an annual health checkup in the Health Management Center of Tianjin Union Medical Center from September to December in 2020 were included in this study. The study was approved by the Medical Ethics Committee of Tianjin Union Medical Center (No. 2021C06) and written informed consents were provided by all the participants.

**Anthropometrical measurement and body composition evaluation**

After an overnight fasting, all participants were instructed to wear in light clothing without shoes and perform anthropometrical evaluations including height and weight. BMI was calculated by weight in kilograms divided by square of height in meters. Body composition including body fat mass (BFM), fat free mass (FFM), skeletal muscle mass (SMM), visceral fat area (VFA) and skeletal muscle index (SMI) was measured by the direct segmental multi-frequency bioelectrical impedance analysis (BIA) method (Inbody 770, Biospace Co., BR-Chinese-C7-B-140218). VSR was the ratio of VFA to SMM. The participants were required to stand upright bare feet with arms straight and hold the handles of the analyzer, so that the palms, thumbs, heels and soles were all in full contact with an 8-pole tactile electrode. Then the measurement began and the data were automatically saved in the computer after the measurement completed.

**Clinical and biochemical measurement**

Past medical histories and demographic characteristics including age, gender were recorded in detail in all of the participants. After a 10-minute rest, blood pressure was measured for three times with an automatic electronic blood pressure monitor (AC-05C, Ling Qian, China) and the mean value was taken. Abdominal ultrasound examination was performed by uniformly trained ultrasound physicians with ultrasound diagnosis system (Philips, Phoenix and Neusoft Medical Systems Co., Ltd., China). All blood samples were collected in the morning after an overnight fasting, centrifuged as soon as possible and stored at \(-80^\circ\text{C}\) for subsequent detection assays. Serum uric acid (SUA), fasting plasma glucose (FPG), total cholesterol (TC), triglycerides (TG), low-density lipoprotein cholesterol (LDL-C) and high-density lipoprotein cholesterol (HDL-C) levels were determined using an automatic biochemical analyzer (TBA120FR, Toshiba, Japan).

**Definitions of cardiometabolic diseases**

Hepatic steatosis was established when two or more of the following requirements given in parentheses were met according to the abdominal ultrasonography (diffuse enhanced echo of liver with liver echogenicity greater than kidney or spleen, deep attenuation of ultrasound signal, vascular blurring). MAFLD was diagnosed as hepatic steatosis with overweight/obesity, T2DM or evidence of metabolic dysregulation \cite{8}. Hyperglycemia was defined as
FPG $\geq 7.0$ mmol/L or previously diagnosed as diabetes. Hypertension was defined as systolic blood pressure (SBP) $\geq 140$ mmHg and/or diastolic blood pressure (DBP) $\geq 90$ mmHg or previously diagnosed as hypertension. Dyslipidemia was defined as TC $\geq 6.2$ mmol/L or LDL-C $\geq 4.1$ mmol/L or HDL-C $< 1.0$ mmol/L or TG $\geq 2.3$ mmol/L based on the Chinese guidelines for the management of dyslipidemia in adults (2016) [9] or previously diagnosed as dyslipidemia. Hyperuricemia was defined as SUA $\geq 420$ μmol/L according to the guideline for the diagnosis and treatment of hyperuricemia and gout in China (2019) [10] or previously diagnosed as hyperuricemia or gout.

**Statistical analysis**

Continuous variables were expressed as mean ± standard deviation or median (interquartile range) and categorical variables were presented as percentage or frequency. Continuous data were analyzed using the independent two-sample t test or the Mann-Whitney U test. Chi-squared test was performed for analysis of categorical variables. Binary logistic regression analysis was adopted to estimate the odds ratio (OR) and 95% confidence interval (CI) between VSR and MAFLD, hyperglycemia, hypertension, dyslipidemia and hyperuricemia. Restricted cubic splines were used to evaluate the non-linear relationships between VSR and the risk of cardiometabolic diseases. Knots were placed at the 33th, 66th and 99th percentiles. All statistical analyses were performed using SAS version 9.4 for Windows (SAS Institute., Cary, NC). P value $<0.05$ was considered to be statistically significant.

**Results**

**Clinical characteristics of the study population**

A total of 5158 participants were recruited in this study, consisting of 2154 men (41.8%) and 3004 women (58.2%). The clinical characteristics of the study population were presented in Table 1. The average age of all the participants was 44.54 ± 14.71 years old, indicating that this was mainly a young and middle-aged population. The overall prevalence of MAFLD, dyslipidemia, hypertension, hyperuricemia and hyperglycemia was 30.9%, 27%, 25.4%, 12.6%, 6.0%, respectively. BMI and some parameters of body composition including BFM, FFM, SMM and SMI were significantly higher in male than in female ($P<0.001$). VFA was obviously higher in female than in male ($P=0.002$), displaying an absolutely opposite trend to that of BMI. Women had relatively high VFA and low SMM, so VSR was significantly higher in women than in men ($P<0.001$). The prevalence of MALFD, hyperglycemia, hypertension, dyslipidemia and hyperuricemia was higher in male than in female ($P<0.001$).

**Prevalence of cardiometabolic diseases according to VSR quartiles in male and female**

According to the VSR quartiles, men and women were divided into four subgroups, respectively. The prevalence of MAFLD, hyperglycemia, hypertension, dyslipidemia and hyperuricemia was calculated in the four subgroups of both genders separately. Results showed that with the increase of VSR, the prevalence of the five cardiometabolic conditions rose up both in male and female. Compared with participants with VSR in the other three quartiles, participants with VSR in the fourth quartile had the highest prevalence of the above-mentioned cardiometabolic diseases ($P<0.001$), regardless of gender. Moreover, in each of the same quartile, the prevalence of cardiometabolic diseases in male was higher than in female ($P<0.001$). The prevalence of MAFLD was the highest among the five cardiometabolic diseases ($P<0.001$). The results were exhibited in Figure 1.

**Associations between VSR and cardiometabolic diseases**
The associations of VSR with cardiometabolic diseases were explored by binary logistic regression analysis and the results were shown in Table 2. We could see that in both genders, VSR was positively correlated with the five cardiometabolic diseases and with the increase of VSR by one quartile, the ORs increased significantly for all the five cardiometabolic diseases ($P_{\text{trend}}<0.001$). With regard to the highest versus the lowest quartile, the ORs for MAFLD, hyperglycemia, hypertension, dyslipidemia and hyperuricemia were 17.23 (95% CI, 12.52-23.71), 15.47 (95% CI, 7.1-33.72), 5.12 (95% CI, 3.88-6.76), 3.16 (95% CI, 2.33-4.28) and 1.89 (95% CI, 1.42-2.51) in male, respectively. And in female, the corresponding ORs were as follows, 41.15 (95% CI, 25.80-65.63), 21.62 (95% CI, 7.87-59.36), 9.64 (95% CI, 6.88-13.53), 9.34 (95% CI, 6.63-13.14) and 6.58 (95% CI, 3.45-12.56). The non-linear relationships of VSR with cardiometabolic diseases in both genders were further explored by restricted cubic splines. Results showed there were significant positive non-linear relationships between VSR and the risk of MAFLD, dyslipidemia, hyperglycemia and hypertension in both genders ($P$ for non-linearity $<0.05$). The risk was relatively flat until when VSR reached $3.078 \text{ cm}^2/\text{kg}$ in men and $4.750 \text{ cm}^2/\text{kg}$ in women and then started to increase rapidly afterwards. In men, however, the risk slowed down after VSR value got to around $4 \text{ cm}^2/\text{kg}$ and the curve became relatively flat and even tended to decline. The non-linear correlations of VSR with hyperuricemia were not statistically significant in both genders, but the previous binary logistic regression analysis had shown significant positive associations between VSR and hyperuricemia ($P_{\text{trend}}<0.001$). The results were shown in Figure 2.

Discussion

The prevalence of obesity is dramatically increasing annually around the world. Due to westernized lifestyle and lack of physical activity, the rise of obesity in China is especially alarming. According to the latest epidemiological survey conducted in China, the national prevalence were 34.3% for overweight and 16.4% for obesity in adults [11], which had been soaring far more than double in the past few decades. There is strong evidence that obesity can lead to increased risks of major cardiometabolic diseases including MAFLD, T2DM, hypertension, dyslipidemia and hyperuricemia. Obesity has become a global public health challenge.

BMI might be a simple and easily accessible index in clinical practice, therefore it is still used as the main criteria for assessing obesity. However, numerous studies have found that individuals considered as overweight or obese by BMI might have no or few cardiometabolic risk factors and even the lowest all-cause mortality [12, 13]. People with similar BMI values might have substantially different levels of health risk [14]. These unexpected findings have come to be termed as the “obesity paradox”. One of the main explanations for mechanisms of the “obesity paradox” might be that these studies used BMI to define obesity, which could not perfectly reflect the amount and distribution of body fat, nor could it precisely differentiate between fat mass and lean body mass [15]. A growing body of evidence has suggested that visceral adiposity and skeletal muscle loss may be both associated with cardiometabolic outcomes. Skeletal muscle loss usually coexists with excessive fat mass, which has come to be known as sarcopenic obesity, a new category of obesity [16]. Based on this fact, we investigated the synergistic effect of visceral fat and skeletal muscle mass on cardiometabolic disorders and explored the gender difference of this association between men and women.

This study was conducted in a natural population undergoing regular health checkup. The mean age of all the participants was around 44 years old, indicating that this study population was mainly middle-aged and was the backbone of social production and development. However, the prevalence of the five cardiometabolic diseases of this population was alarming, with MAFLD being the highest (30.9%), followed by dyslipidemia (27%),
hypertension (25.4%), hyperuricemia (12.6%) and hyperglycemia (6.0%). These prevalence rates were similar to those found in previous epidemiological studies in Chinese ethnic except for hyperglycemia [17, 18, 19]. According to the latest epidemiological survey, the prevalence of diabetes in China is around 12.8% [20], which is much higher than the result in our study. This discrepancy may be attributed to the fact that some patients with T2DM may have elevated postprandial blood glucose at the early stage of the disease, but their FPG can be still remained in the normal range [21]. The data in this study came from a population receiving their annual health checkup, with only one fasting blood sample taken and FPG measured, which might miss some diabetic patients. In addition, participants recruited in this study were mainly young and middle-aged people, which might also lead to the relatively low prevalence of hyperglycemia. Since there exist considerable differences in both body fat distribution and mass of body fat and skeletal muscle between men and women due to different sex hormone levels, all the participants were divided into two groups by gender. We can see that BMI, BFM, FFM, SMM and SMI were significantly higher in male than in female. VFA as the most critical risk factor for cardiometabolic diseases, however, was obviously higher in female than that in male, displaying an absolutely opposite trend to that of BMI. Thus, VSR calculated as the ratio of VFA to SMM was significantly higher in women than in men.

Based on the quartiles of VSR, men and women were further divided into four subgroups, respectively. Results showed that with the increase of VSR, the prevalence of the five cardiometabolic diseases rose up both in male and female. Participants with VSR in the fourth quartile had the highest prevalence of the above-mentioned cardiometabolic diseases, regardless of gender. This suggested that VSR was positively associated with the development of cardiometabolic diseases. To our knowledge, this is the first study that evaluates the relationship between VSR and cardiometabolic diseases in relatively large-scale natural population in China. In addition, in each of the same quartile, the prevalence of cardiometabolic diseases in male was higher than in female, which is consistent with the outcomes of previous researches [22]. Of note, MAFLD may be more common in postmenopausal women than in men, for women in this stage have lost the protective effect of estrogen [23]. The prevalence of MAFLD was the highest among the five cardiometabolic diseases, which might owe to the strong correlations between low muscle mass or sarcopenia and MAFLD [24].

To further clarify the associations between VSR and cardiometabolic diseases, we then performed binary logistic regression analysis. Results showed that VSR was positively correlated with the five cardiometabolic diseases and with the increase of VSR by one quartile, the ORs increased significantly for all the five cardiometabolic diseases both in male and female, which further robustly confirmed the associations between VSR and cardiometabolic diseases. With regard to the highest versus the lowest quartile, the ORs for the five diseases were dramatically higher in female than in male, which meant that the risk of these cardiometabolic diseases was obviously higher in female than in male. Furthermore, we used restricted cubic splines to visualize the relations of VSR with the five cardiometabolic diseases in men and women. We found that there were significant positive non-linear relationships between VSR and the risk of MAFLD, dyslipidemia, hyperglycemia and hypertension in both genders (P for non-linearity <0.05). Nevertheless, there were still differences between men and women. In women, the risk started to rise up rapidly after VSR reached a certain threshold. In men, however, the risk increased initially but tended to slow down when VSR arrived at a certain value and the curve became flat and even tended to decline. This also indicated that as VSR increased, the risk of cardiometabolic diseases was higher in women than in men, consistent with the result of binary logistic regression analysis. Similar results are found in numerous previous studies, which have shown that compared with men, women have greater risk of cardiometabolic diseases, such as MAFLD, diabetes, cardiovascular disease and hypertriglyceridemia [25, 26].
There are several strengths in our study. First of all, this is the first analysis to examine the associations of the joint effect of visceral fat and skeletal muscle mass on cardiometabolic disorders in a large natural population of Chinese ethnic. Secondly, this study has clarified gender differences of these associations based on the significant differences of body composition in men and women. Thirdly, we have used restricted cubic spline curves to clearly visualize the non-linear relationships between VSR and cardiometabolic diseases when they are not linearly related. The study also has several limitations. Firstly, this is a cross-sectional study, which can not prove the causality between VSR and cardiometabolic diseases. Secondly, body composition has been measured by BIA method, which is not the most perfect way to measure actual body lean mass and fat mass. However, BIA is a relatively simple and harmless yet reliable and popular tool for assessing body composition. Thirdly, the participants enrolled in this study were those who received their annual health checkup and only their fasting blood samples could be obtained, which might lead to the missed diagnosis of some patients with hyperglycemia.

**Conclusions**

In conclusion, our results suggested that VSR was positively associated with cardiometabolic diseases regardless of gender. As VSR increased, the risk of cardiometabolic diseases in women was significantly higher than in men. These results indicated that women should be more alert to the risk of cardiometabolic diseases caused by the increase of VSR than men. Well-designed, prospective cohort studies including larger sample sizes, other age and ethnic groups are needed to further confirm and replicate our conclusions.

**Declarations**

**Ethics approval and consent to participate**

The study was approved by the Medical Ethics Committee of Tianjin Union Medical Center (No. 2021C06) and written informed consents were provided by all the participants.

**Consent for publication**

Not applicable.

**Availability of data and materials**

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

**Competing interests**

The authors declare that they have no competing interests.

**Funding**

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**Authors' contributions**
SZ analyzed and interpreted the patient data and was the major contributor in writing the manuscript. YPH analyzed and interpreted the data. JL, MYZ, XCW, YJZ and MY D assisted with data collection. XHW assisted with data analyses. CJL and JNL contributed to the design of the study. All authors read and approved the final manuscript.

**Acknowledgements**

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**References**


Tables
Table 1: Characteristics of the study population according to gender

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Total (N= 5, 158)</th>
<th>Male (N= 2, 154)</th>
<th>Female (N= 3, 004)</th>
<th>p*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>44.54 ± 14.71</td>
<td>45.48 ± 15.0</td>
<td>43.86 ± 14.47</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Height, cm</td>
<td>165.46 ± 8.31</td>
<td>172.36 ± 6.31</td>
<td>160.51 ± 5.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>66.78 ± 13.17</td>
<td>76.71 ± 11.58</td>
<td>59.65 ± 8.95</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>24.26 ± 3.63</td>
<td>25.78 ± 3.36</td>
<td>23.17 ± 3.41</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SBP, mmHg</td>
<td>122.66 ± 17.88</td>
<td>127.91 ± 16.45</td>
<td>118.89 ± 17.91</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>DBP, mmHg</td>
<td>77.46 ± 10.56</td>
<td>80.66 ± 10.53</td>
<td>75.16 ± 9.97</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>TG, mmol/L</td>
<td>1.13 (0.81 ~ 1.63)</td>
<td>1.35 (0.99 ~ 1.91)</td>
<td>1.0 (0.74 ~ 1.42)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>HDL-C, mmol/L</td>
<td>1.55 ± 0.38</td>
<td>1.39 ± 0.3</td>
<td>1.67 ± 0.38</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LDL-C, mmol/L</td>
<td>2.71 ± 0.58</td>
<td>2.69 ± 0.55</td>
<td>2.73 ± 0.61</td>
<td>0.004</td>
</tr>
<tr>
<td>SUA, umol/L</td>
<td>311.02 ± 82.31</td>
<td>368.2 ± 74.72</td>
<td>270.03 ± 60.06</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BFM, kg</td>
<td>20.41 ± 6.46</td>
<td>20.99 ± 6.8</td>
<td>19.99 ± 6.18</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>FFM, kg</td>
<td>46.35 ± 9.66</td>
<td>55.68 ± 6.95</td>
<td>39.66 ± 4.29</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SMM, kg</td>
<td>25.45 ± 5.87</td>
<td>31.15 ± 4.19</td>
<td>21.35 ± 2.56</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>VFA, cm²</td>
<td>95.07 ± 36.01</td>
<td>93.23 ± 34.35</td>
<td>96.38 ± 37.1</td>
<td>0.002</td>
</tr>
<tr>
<td>VSR, cm²/kg</td>
<td>3.88 ± 1.62</td>
<td>3.00 ± 1.06</td>
<td>4.51 ± 1.66</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SMI, kg/m²</td>
<td>6.97 ± 1.08</td>
<td>7.98 ± 0.7</td>
<td>6.25 ± 0.61</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MAFLD, n (%)</td>
<td>1594 (30.9)</td>
<td>948 (44.0)</td>
<td>646 (21.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hyperglycemia, n (%)</td>
<td>312 (6.0)</td>
<td>185 (8.6)</td>
<td>127 (4.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hypertension, n (%)</td>
<td>1309 (25.4)</td>
<td>746 (34.6)</td>
<td>563 (18.7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Dyslipidemia, n (%)</td>
<td>1394 (27.0)</td>
<td>669 (31.1)</td>
<td>725 (24.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hyperuricemia, n (%)</td>
<td>648 (12.6)</td>
<td>506 (23.5)</td>
<td>142 (4.7)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Note: * Student t-test, unpaired Mann-Whitney U-test or chi-squared test was performed where appropriate.

Abbreviations: BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose; TC, total cholesterol; TG, triglycerides; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SUA, serum uric acid; BFM, body fat mass; FFM, fat free mass; SMM, skeletal muscle mass; VFA, visceral fat area; VSR, visceral fat area to skeletal muscle mass ratio; SMI, skeletal muscle index; MAFLD, metabolic associated fatty liver diseases.
Table 2 OR with 95% CI for associations between VSR and cardiometabolic diseases according to gender

<table>
<thead>
<tr>
<th>VSR (cm²/kg)</th>
<th>N</th>
<th>MAFLD</th>
<th>Hyperglycemia</th>
<th>Hypertension</th>
<th>Dyslipidemia</th>
<th>Hyperuricemia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q1*</td>
<td>539</td>
<td>1 (ref.)</td>
<td>1 (ref.)</td>
<td>1 (ref.)</td>
<td>1 (ref.)</td>
<td>1 (ref.)</td>
</tr>
<tr>
<td>Q2</td>
<td>538</td>
<td>4.75 (3.47, 6.50)</td>
<td>5.13 (2.25, 11.67)</td>
<td>1.90 (1.42, 2.54)</td>
<td>1.95 (1.42, 2.68)</td>
<td>1.17 (0.86, 1.58)</td>
</tr>
<tr>
<td>Q3</td>
<td>539</td>
<td>9.18 (6.72, 12.53)</td>
<td>8.29 (3.73, 18.4)</td>
<td>2.95 (2.23, 3.90)</td>
<td>2.65 (1.94, 3.60)</td>
<td>1.41 (1.05, 1.89)</td>
</tr>
<tr>
<td>Q4</td>
<td>538</td>
<td>17.23 (12.52, 23.71)</td>
<td>15.47 (7.1, 33.72)</td>
<td>5.12 (3.88, 6.76)</td>
<td>3.16 (2.33, 4.28)</td>
<td>1.89 (1.42, 2.51)</td>
</tr>
<tr>
<td>P trend</td>
<td></td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q1</td>
<td>751</td>
<td>1 (ref.)</td>
<td>1 (ref.)</td>
<td>1 (ref.)</td>
<td>1 (ref.)</td>
<td>1 (ref.)</td>
</tr>
<tr>
<td>Q2</td>
<td>751</td>
<td>3.10 (1.83, 5.21)</td>
<td>3.80 (1.25, 11.49)</td>
<td>2.40 (1.66, 3.49)</td>
<td>2.41 (1.65, 3.50)</td>
<td>2.12 (1.03, 4.38)</td>
</tr>
<tr>
<td>Q3</td>
<td>751</td>
<td>10.60 (6.58, 17.06)</td>
<td>7.76 (2.72, 22.14)</td>
<td>3.64 (2.55, 5.20)</td>
<td>4.38 (3.07, 6.24)</td>
<td>3.88 (1.98, 7.61)</td>
</tr>
<tr>
<td>Q4</td>
<td>751</td>
<td>41.15 (25.80, 65.63)</td>
<td>21.62 (7.87, 59.36)</td>
<td>9.64 (6.88, 13.53)</td>
<td>9.34 (6.63, 13.14)</td>
<td>6.58 (3.45, 12.56)</td>
</tr>
<tr>
<td>P trend</td>
<td></td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Note: quartiles of VSR in male, Q1: 0.35 ~ 2.28, Q2: 2.29 ~ 2.86, Q3: 2.87 ~ 3.56, Q4: 3.57 ~ 8.84; quartiles of VSR in female, Q1: 1.24 ~ 3.16, Q2: 3.17 ~ 4.27, Q3: 4.28 ~ 5.59, Q4: 5.60 ~ 11.32.

Abbreviations: OR, odds ratio; CI, confidence interval; VSR, visceral fat area to skeletal muscle mass ratio; MAFLD, metabolic associated fatty liver disease.

Figures

**Figure 1**

Prevalence of cardiometabolic diseases grouped by VSR quartiles.
Note: quartiles of VSR in male, Q1: 0.35 ~ 2.28, Q2: 2.29 ~ 2.86, Q3: 2.87 ~ 3.56, Q4: 3.57 ~ 8.84; quartiles of VSR in female, Q1: 1.24 ~ 3.16, Q2: 3.17 ~ 4.27, Q3: 4.28 ~ 5.59, Q4: 5.60 ~ 11.32.

Abbreviations: VSR, visceral fat area to skeletal muscle mass ratio; MAFLD, metabolic associated fatty liver disease.

Figure 2

Non-linear relationships between VSR and risk of cardiometabolic diseases in male and female.

Note: data were OR (solid line) and 95% CI (shadow area) from logistic regression analysis with restricted cubic splines.

Abbreviations: VSR, visceral fat area to skeletal muscle mass ratio; MAFLD, metabolic associated fatty liver disease; OR, odds ratio; CI, confidence intervals.