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Optimal cut-points of visceral adipose tissue areas for cardiometabolic risk factors in a Chinese population: a cross-sectional study

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Abstract

Aim To determine the optimal cut-points of visceral adipose tissue (VAT) areas at different anatomic levels to discriminate participants with cardiometabolic risk factors in a Chinese middle-aged population.

Methods A total of 1744 individuals who underwent regular health checks in Nanjing BENQ Medical Center from January 2013 to December 2016 were included in this cross-sectional study. VAT areas were measured by abdominal quantitative computed tomography at the L2/3 intervertebral disk and umbilicus levels. Cardiometabolic risk factors including serum triglycerides, HDL cholesterol levels, plasma glucose and blood pressure were defined using IDF 2005 criteria for metabolic syndrome.

Results The cut-points for VAT area at the umbilicus level were 111 cm^2 for men and 96 cm^2 for women to identify people with one or more cardiometabolic risk factors. For VAT area at the L2/3 level, the optimal cut-points were 142 cm^2 for men and 115 cm^2 for women. A VAT area at the L2/3 level of $\geq$ 142 cm^2 for men or 115 cm^2 for women significantly increased the prevalence of hyperglycaemia [odds ratio (OR) 3.18, 95% confidence interval (CI) 2.45–4.13], hypertension (OR 2.81, 95% CI 2.27–3.49) and dyslipidaemia (OR 4.37, 95% CI 3.50–5.45) after adjusting age.

Conclusions The optimal cut-points for VAT area at the umbilicus level and L2/3 level were 111 cm^2 and 142 cm^2 for men and 96 $cm^2$and 115 cm^2 for women to identify participants with one or more cardiometabolic risk factors.

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Introduction

Obesity has become a significant public health problem worldwide. Fat deposition, particularly visceral fat, increases the risk of diabetes, dyslipidaemia, hypertension, metabolic syndrome, cardiovascular disease, sleep apnoea and cancer [1–3]. Overweight and obesity are often defined by anthropometric measures, including BMI, waist circumference and waist-to-hip ratio. While BMI typically represents the total body mass, waist circumference and waist-to-height ratio are more reflective of abdominal obesity. It has now become clear that the way in which fat is distributed is an important factor in regard to the assessment of cardiometabolic risk [4,5]. Subcutaneous adipose tissue has a limited capacity for adipose expansion, which varies widely between individuals [6]. Once the capacity is exceeded, adipose tissue ceases to store energy efficiently and ectopic fat deposition occurs. Visceral adipose tissue (VAT) is a marker of ectopic fat deposition that has been demonstrated to cause lipotoxic insults including insulin resistance, apoptosis and inflammation, and to have an important role in mediating cardiovascular risk [5,7]. A significant independent relationship between visceral adiposity and cardiovascular diseases was reported in the Framingham Heart study even after adjusting for BMI [8]. By contrast, studies have reported no association of cardiovascular disease with the amount of subcutaneous adipose tissue [8,9]. Further characterization of the role of VAT in the metabolic syndrome has therefore been recommended [10].

Computed tomography (CT) and magnetic resonance imaging (MRI) provide a means of accurately quantifying fat distribution. Multiple volume imaging is recognized as

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What's new?

- This study aimed to investigate the optimal cut-points of visceral adipose tissue (VAT) areas by means of computed tomography (CT) scanning to discriminate participants with cardiometabolic risk factors in a Chinese middle-aged population.
- The results showed that the optimal cut-points for VAT area at the umbilicus level were 111 cm^2 for men and 96 cm^2 for women to identify participants with one or more cardiometabolic risk factors, which was 142 cm^2 for men and 115 cm^2 for women for VAT area at the L2/3 level.
- VAT area at the L2/3 level had comparable power with VAT area at the umbilicus level to identify participants with cardiometabolic risk factors.
- Such information of setting up ethnic- and sex-specific cut-points for VAT areas is of clinical and economic importance for risk assessment.

the gold standard for such measures. However, this is time-consuming, costly and (for CT) involves high radiation exposure. Many studies have demonstrated that VAT measured in a single CT or MRI slice through the abdomen correlates significantly with the total volume of VAT, and is therefore a good proxy for total visceral fat accumulation [11–13]. The most common location for the single slice has been at the level of the umbilicus or L4/5 level, partly for reasons of ease of identification of the umbilicus. In our previous study, we demonstrated that VAT area measurements at the L2/3 slice were more strongly correlated with total VAT volume than were other slices, and suggested that this was the optimal site for such measurements [14,15].

Along with early diagnosis of obesity, it is important to consider population-specific issues in setting cut-points, as the distribution of abdominal fat varies among different ethnic groups. One study reported that, in comparison with four other ethnic groups, East Asian men and women had the largest relative accumulation of VAT despite having lower levels of total adiposity [16]. The Japanese Visceral Fat Syndrome Study reported the cut-point of VAT area of 100 cm^2 at the umbilical level scanned by CT as being the optimal value for identifying risk of disorders related to obesity [17]. However, similar studies investigating VAT area cut-points derived from CT in the Chinese population are limited. The objective of this study was to establish the optimal cut-points of VAT areas at different anatomic sites to discriminate people with cardiometabolic risk factors in a Chinese middle-aged population and to compare the performance of VAT area at L2/3 level with VAT area at umbilicus level and BMI.

Methods

Study population

A total of 1744 people underwent regular health checks in Nanjing BENQ Medical Center from January 2013 to December 2016. Medical history was obtained during the health check-ups. Participants with following conditions were excluded: (i) current treatment with systemic corticosteroids; (ii) known hyperthyroidism or hypothyroidism; (iii) cirrhosis accompanied by ascites; (iv) presence of cancer; (v) psychiatric disturbance or severe disability; and (vi) pregnancy. Informed consent was obtained from all participants. The study was approved by the Ethics Committee of Beijing Jishuitan Hospital and the Ethics Committee of Nanjing BENQ Medical Center, and the study conforms to the Declaration of Helsinki.

Anthropometric measurements and blood tests

Anthropometric measurements were collected by trained nurses, adhering to standardized techniques. Height was measured using a stadiometer and weight was measured using an electronic scale. BMI was calculated as weight in kilograms divided by the square of the height in metres. Blood pressure (BP) was measured twice with a mercury sphygmomanometer in the sitting position (HEM-907; Omron Healthcare Company, Kyoto, Japan), and was rounded to the nearest 2 mmHg. The mean of the readings was recorded. Venous blood samples were taken by nurses and the laboratory at Nanjing BENQ Medical Center was used for fasting plasma glucose (glucose oxidase method) and lipid profile testing (HDL cholesterol and triglycerides – enzymatic method) using an autoanalyser (Hitachi 7600-110E/ Hitachi 7180E; Hitachi, Tokyo, Japan).

Definition of the cardiometabolic risk factors

The cardiometabolic risk factors were defined using the 2005 IDF criteria for metabolic syndrome [10], with the exception of waist circumference as follows: (i) serum triglycerides levels $\geq$ 150 mg/dl or specific treatment for this lipid abnormality; (ii) serum HDL cholesterol levels < 40 mg/dl in men, < 50 mg/dl in women or specific treatment for this lipid abnormality; (iii) fasting plasma glucose $\geq$ 100 mg/dl or previously diagnosed Type 2 diabetes; and (iv) BP $\geq$ 130/85 mmHg or treatment for previously diagnosed hypertension.

The protocol of CT scan

CT was performed using a 64-detector row scanner (Lightspeed VCT Vision; GE Healthcare, Milwaukee, WI, USA). Scan parameters were 120 kV, 100 mAs, 1 mm slice thickness, field of view 40 cm. The quantitative computed tomography (QCT) calibration phantom (Mindways, Austin, TX, USA) was placed beneath the participants and scanned simultaneously.

The measurements of VAT

CT scanning was performed by qualified technicians according to the CT scan protocol. CT raw data in QCT format were transferred to the Department of Radiology, Beijing Jishuitan Hospital for imaging analysis. VAT measurements were performed at two slices (L2/3 intervertebral space and the umbilicus level) by trained and qualified radiologists, using Mindways QCT software. Details of adipose tissue measurements have been reported previously [18]. In brief, adipose tissue was segmented and mapped in blue with a default threshold, and the outer contour of abdominal wall was then outlined by the software automatically on each 1 mm-thick slice. VAT areas (cm^2) were determined by semiautomated segmentation using the Tissue Composition Module of the Mindways software and the results were exported to Excel.

Statistical analysis

The predictive power and the cut-points for VAT and total adipose tissue (TAT) areas at different anatomic levels and BMI as discriminators of cardiometabolic risk factors were determined using receiver operating characteristic (ROC) curves. The area under the ROC curve (AUC) was identified for VAT and TAT areas at different anatomic levels and BMI. The larger the AUC, the greater the discriminatory power of each indicator for cardiometabolic risk factors. The confidence interval (CI) was set at 95%. A 95% CI which excluded a lower limit of the AUC of < 0.50 was used to indicate a statistically significant association. The Youden index [maximum (sensitivity + specificity−1)] was used to identify optimal cut-points [19]. The score with the highest Youden index was considered the optimal cut-point score. Logistic regression analysis was used to estimate the prevalence ratio (95% CI) among those with hyperglycaemia, hypertension and dyslipidaemia (dependent variables). In these analyses, the cut-points of VAT area at the L2/3 level served as the independent variable and age (continuous) as a covariate. Statistical significance was defined as two-tailed $P < 0.05$. Data were analysed using SPSS version 19.0 (SPSS Inc., Chicago, IL, USA) for Windows. The diagnostic abilities between indicators were compared using Medcalc software.

Results

Study characteristics

The general characteristics of the participants are shown in Table 1. Of the 1744 participants, 1093 (62.7%) were men and 651 (37.3%) were women, and the median age was 50 years (IQR 43–59). Mean BMI was 25.8 kg/m^2 (SD 3.2) for men and 23.9 kg/m^2 (SD 3.2) for women. The following prevalence percentages were observed: 32.7% for hyperglycaemia, 52.6% for hypertension, 45.3% for hypertriglyceridemia and 26.4% for low HDL cholesterol among men; and 19.7% for hyperglycaemia, 37.5% for hypertension, 22.1% for hypertriglyceridemia and 26.4% for low HDL cholesterol among women. There were 1228 participants (70.4%) who had at least one cardiometabolic risk factor.

Predictability and the cut-points of VAT areas, TAT areas and BMI for identifying the presence of one or more cardiometabolic risk factors

AUC values of VAT and TAT areas at different anatomic sites and BMI for identifying the presence of one or more cardiometabolic risk factors are presented in Table 2. In both men and women, the AUC for VAT area at the L2/3 level showed no statistically significant difference with VAT area at the umbilicus level in distinguishing people with one or more cardiometabolic risk factors (Table 1), or any of

Table 1 General characteristics of the study participants

	Total	Males	Females
N (%)	1744 (100)	1093 (62.7)	651 (37.3)
Age, years	50 (43–59)	49 (43–58)	52 (44–61)
BMI, kg/m^2*	25.1±3.3	25.8±3.2	23.9±3.2
SBP, mmHg	126 (115–139)	129 (118–140)	121 (110–137)
DBP, mmHg	78 (70–87)	81 (73–88)	73 (65–81)
Fasting plasma glucose, mmol/l	5.3 (4.9–5.7)	5.4 (5.0–5.8)	5.1 (4.8–5.5)
HDL cholesterol, mmol/l	1.32 (1.08–1.60)	1.20 (1.01–1.44)	1.52 (1.28–1.79)
Triglycerides, mmol/l	1.37 (0.95–2.08)	1.57 (1.11–2.34)	1.09 (0.78–1.62)
TAT areas at the L2/3 level, cm^2	255 (190–317)	264 (204–331)	232 (166–299)
VAT areas at the L2/3 level, cm^2	152 (106–200)	179 (135–224)	110 (78–146)
TAT areas at the umbilicus level, cm^2	249 (190–312)	255 (197–319)	238 (183–301)
VAT areas at the umbilicus level, cm^2	116 (84–153)	134 (103–169)	92 (68–122)

Values are given as median (IQR), except *mean±SD.
VAT, visceral adipose tissue; TAT, total adipose tissue.

cardiometabolic risk factors (Table S1). VAT area at the L2/3 level had greater AUC values compared with TAT areas at the L2/3 or umbilicus level in distinguishing men with one or more cardiometabolic risk factors, or hyperglycaemia or dyslipidaemia. For women, VAT area at the L2/3 level showed higher AUC values than TAT area at the umbilicus level in identifying the presence of one or more cardiometabolic risk factors, or any of cardiometabolic risk factors; however, no statistically significant differences were observed between the AUC values of VAT area at the L2/3 level and TAT area at the L2/3 level. In addition, VAT area at the L2/3 level showed higher AUC values than BMI in distinguishing men with one or more cardiometabolic risk factors, or men with dyslipidaemia.

Table 2 also shows the sensitivities and specificities for each cut-point and their VAT and TAT areas at different anatomic levels and BMI as discriminators of one or more cardiometabolic risk factors. The optimal cut-points of VAT area at the L2/3 level for identifying the presence of one or more cardiometabolic risk factors were 142 cm^2 for men and 115 cm^2 for women. For a VAT area at the L2/3 level of 142 cm^2 in men the sensitivity was 0.803 and the specificity was 0.544, whereas for a VAT area of 115 cm^2 in women the sensitivity was 0.629 and the specificity was 0.751. For VAT area at the umbilicus level, the optimal cut-points were 111 cm^2 for men and 96 cm^2 for women. For BMI, the optimal cut-points were 25.3 kg/m^2 for men and 22.8 kg/m^2 for women.

The relationships between cut-points of VAT area at the L2/3 level (142 cm^2 for men and 115 cm^2 for women) and cardiometabolic risk factors are shown in Table 3. The presence of VAT area at the L2/3 level ≥ 142 cm^2 for men or 115 cm^2 for women was statistically significantly associated for either sex (P < 0.001) with higher BMI, systolic BP, diastolic BP, fasting plasma glucose, triglycerides and lower HDL cholesterol. For women, those with VAT area at the L2/3 level ≥ 115 cm^2 were statistically significantly older. There was no statistically significant difference in age for men with VAT area at the L2/3 level ≥ 142 cm^2 compared with < 142 cm^2 (P = 0.338; Table 3).

The associations of the prevalence of cardiometabolic risk factors with the suggested cut-points for VAT area at the L2/3 level are presented in Table 4. Significant associations of this VAT area at the L2/3 level with hyperglycaemia, hypertension and dyslipidaemia were observed independently of age. The presence of VAT area at the L2/3 level ≥ 142 cm^2 for men or 115 cm^2 for women significantly increased the prevalence of hyperglycaemia [odds ratio (OR) 3.18, 95% CI 2.45–4.13], hypertension (OR 2.81, 95% CI 2.27–3.49) and dyslipidaemia (OR 4.37, 95% CI 3.50-5.45) even after adjusting for age.

Discussion

During the past 10 years or so, many studies have shown that visceral fat is more strongly associated with the risk of

Table 2 AUC (95% CI) and cut-points of visceral adipose tissue (VAT) area and total adipose tissue areas (TAT) area measured at the L2/3 level and umbilicus level to identify the presence of one or more cardiometabolic risk factors

	Males (n = 1093)					Females (n = 651)				
	ROC curve area (95% CI)	P-value compared with VAT area measured at the L2/3 level	Cut-point	Sensitivity	Specificity	ROC curve area (95% CI)	P-value compared with VAT area measured at the L2/3 level	Cut-point	Sensitivity	Specificity
VAT area measured at the L2/3 level (cm^2)	0.725 (0.684, 0.765)		142	0.803	0.544	0.726 (0.685, 0.768)		115	0.629	0.751
TAT area measured at the L2/3 level (cm^2)	0.703 (0.661, 0.745)	0.0036	242	0.714	0.617	0.711 (0.669, 0.754)	0.0609	268	0.501	0.838
VAT area measured at the umbilicus level (cm^2)	0.715 (0.674, 0.756)	0.3379	111	0.764	0.573	0.727 (0.686, 0.769)	0.9433	96	0.612	0.764
TAT area measured at the umbilicus level (cm^2)	0.689 (0.646, 0.731)	0.0010	222	0.764	0.544	0.686 (0.642, 0.730)	0.0041	248	0.600	0.686
BMI (kg/m^2)	0.693 (0.653, 0.734)	0.0198	25.3	0.634	0.670	0.701 (0.658, 0.744)	0.0947	22.8	0.745	0.590

VAT, visceral adipose tissue; TAT, total adipose tissue.

Table 3 Cardiometabolic risk factors in relation to cut-points for visceral adipose tissue area measured at the L2/3 level

	Cut-points for VAT area measured at the L2/3 level					
	Males			Females		
	< 142cm^2 (n = 296)	≥ 142cm^2 (n = 747)	P-value	<115 cm^2 (n = 329)	≥ 115cm^2 (n = 295)	P-value
Age, years	45 (38, 55)	46 (40, 54)	0.338	44 (37, 52)	53 (46, 62)	< 0.001
BMI, kg/m^2*	23.1 ± 2.4	26.9 ± 2.8	< 0.001	22.1 ± 2.3	26.0 ± 2.9	< 0.001
SBP, mmHg	122 (113, 132)	130 (120,142)	< 0.001	117 (106, 129)	130 (117, 147)	< 0.001
DBP, mmHg	74 (69, 83)	82 (75, 90)	< 0.001	68 (62, 76)	77 (70, 86)	< 0.001
Fasting plasma glucose, mmol/l	5.21 (4.91, 5.53)	5.41 (5.06, 5.92)	< 0.001	5.02 (4.75, 5.27)	5.31 (4.97, 5.75)	< 0.001
HDL cholesterol, mmol/l	1.36 (1.12, 1.60)	1.14 (0.98, 1.37)	< 0.001	1.64 (1.40, 1.88)	1.37 (1.18, 1.61)	< 0.001
Triglycerides, mmol/l	1.19 (0.85, 1.72)	1.77 (1.24, 2.57)	< 0.001	0.92 (0.69, 1.20)	1.41 (1.00, 2.02)	< 0.001

Values are given as median (IQR), except *mean±SD.
VAT, visceral adipose tissue.

Table 4 Prevalent ratio of cardiometabolic risk factors in relation to cut-points for visceral adipose tissue area at the L2/3 level calculated using a univariate and multivariate regression analysis according to Poisson

	VAT area measured at the L2/3 level #	
	Non adjusted	Adjusted by age
High fasting plasma glucose	3.42 (2.64, 4.43)	3.18 (2.45, 4.13)
High BP	3.06 (2.48, 3.77)	2.81 (2.27, 3.49)
Hypertriglyceridaemia and/or low HDL* cholesterol	4.25 (3.42, 5.29)	4.37 (3.50, 5.45)

*≥ 142 cm^2 for men and ≥ 115cm^2 for women
VAT, visceral adipose tissue.

a variety of health conditions than is BMI [5,20,21]. The contribution of VAT is greater in East Asians in whom total fat accumulation is typically less than in Western populations [16]. In this study, we investigated the association of cardiometabolic risk factors with VAT areas using CT scanning in a Chinese middle-aged population and found that the cut-points for VAT area at the umbilicus level were 111 cm^2 for men and 96 cm^2 for women to identify people with one or more cardiometabolic risk factors. For VAT area at the L2/3 level, the optimal cut-points were 142 cm^2 for men and 115 cm^2 for women. According to the IDF, ethnic-specific and sex-specific cut-off values should be used to define central obesity. The Japan Society for the Study of Obesity proposed VAT at the umbilical level scanned by CT > 100 cm^2 to define abdominal obesity for both men and women [17]. However, a Korean study recommended the optimal VAT cut-off values to identify increased metabolic risk were 100 cm^2 for men and 70 cm^2 for women [22]. Although the cut-point values in our study were higher than those calculated for the Korean population, there were marked sex differences in VAT cut-points in both our study and the Korean study. Such differences between men and women in both total adiposity and distribution of adipose tissue have been reported frequently. Women generally have greater total body fat content and a higher proportion located in the gluteofemoral region. Men, by contrast, are more predisposed to deposit fat intra-abdominally – a condition that has been described as visceral obesity [5,20,23].

Many previous studies had demonstrated that the measurement site of VAT had an impact on the association between VAT and health risk factors and suggested that an image located in the upper abdominal region (L2/3 or L3/4) rather than the L4/5 level would better characterize the association of VAT with the metabolic syndrome in men [12,24,25]. However, the impact of the level of the CT slice is somewhat less in women. Our previous study showed that VAT area measurements at the L2/3 slice had the strongest association with the total VAT volume [14]. In the present study, we found that the AUC for VAT area at the L2/3 level seemed to have higher values than VAT area at the umbilicus level in distinguishing men with one or more cardiometabolic risk factors, but a statistically significant difference was not observed. Moreover, with the upper abdominal CT images available, more valuable information including bone mineral density of the vertebrae and the liver fat assessments can be obtained in a single exam with the minimal dose of radiation. Therefore, it may be also efficient in health economic terms to evaluate osteoporosis, obesity and hepatic steatosis (and non-alcoholic fatty-liver disease in general) simultaneously on a single-CT scan. These findings showed that an upper abdominal image (L2/3) might be an optimal location for the assessment of VAT.

BMI, a traditional anthropometric measurement, represents the total body mass and is the most widely used clinical marker of adiposity. Studies show that the discriminatory power of BMI for VAT or cardiovascular risk factors varied with age, sex and ethnic group. In a study of 690 Chinese adults, BMI exhibited a good AUC as a discriminator of visceral abdominal obesity [26]. In our study, VAT area at the L2/3 level had better discriminative ability than BMI to detect men with one or more cardiometabolic risk factors or men with dyslipidaemia, but did not perform statistically significantly better than BMI in women. A recent study that analysed the performance of anthropometry in predicting VAT among 255 postmenopausal women, found that BMI displayed similar AUC with waist circumference [27]. The optimal cut-points for BMI were 25.3 kg/m^2 for men and 22.8 kg/m^2 for women. The World Health Organization and National Institutes of Health use BMI values of 25 and 30 kg/m^2 to define overweight and obesity [28,29]. China adopts the criteria of 24 and 28 kg/m^2 to define obesity in both men and women. However, it is controversial to use a universal BMI cut-score to define obesity irrespective of sex [30,31]. At any given BMI, the body fat percentage of women is typically over 10% higher than that of men [31]. A study including 36 642 Taiwanese adults reported the optimal BMI cut-off values for predicting diabetes, hypertension, metabolic syndrome, and dyslipidaemia varied between 24.5 and 25.7 kg/m^2 among men, and between 22.6 and 24.0 kg/m^2 among women [32]. Our results are consistent with this Taiwan study, showing that sex and ethnicity are important considerations when determining criteria of BMI for overweight and obesity.

In addition, our findings showed significant associations of the cut-points for VAT area at the L2/3 level with each cardiometabolic risk factor assessed in this population. Thus, higher values for serum lipid profile (serum triglycerides and HDL cholesterol), BP and blood glucose in participants with VAT area at the L2/3 level $\geq$ 142 cm^2 for men or $\geq$ 115 cm^2 for women were observed. In addition, the prevalence of each cardiometabolic risk factor was even higher in participants with VAT area at the L2/3 level $\geq$ 142 cm^2 for men or $\geq$ 115 cm^2 for women. Previous studies have reported a strong association between obesity and other cardiovascular risk factors, especially when using measures of central fat. Thus, our data reinforce the finding of an association between VAT and cardiometabolic risk factors that has been reported previously among different ethnic populations and support the idea that the ethnic- and sex-specific cut-points for VAT areas are of clinical and economic importance for risk assessment.

Although this was a large study, and used CT scanning to determine VAT, it is important to note some of the study limitations. First, the reported associations cannot be used to infer causality, because of the cross-sectional nature of the study. A prospective study with the power to examine the development of risk factors as well as the development of cardiovascular events would provide a better means of identifying cut-points. Second, our population was derived from a hospital setting so findings may not be generalizable to other population groups. Third, in most of the definitions of metabolic syndrome, waist circumference is used to evaluate central obesity; however, waist circumference is not measured routinely in the regular health checks in China. Because of the unavailability of waist circumference data, we could not compare the predictability for identifying the presence of one or more cardiometabolic risk factors between waist circumference and VAT scanned by CT in our study. Furthermore, several risk factors (alcohol intake, smoking, physical activity levels and menopausal status) that may be related to visceral adiposity were not accounted for. Finally, the numerical imbalance between men and women, and the specific characteristics of individuals recruited to the study may have an impact on how these results should be interpreted. Prospective studies should be designed to determine the most appropriate cut-points for VAT in community-based populations.

In conclusion, QCT provides accurate and reliable measurements of abdominal visceral obesity. Given our evidence, the optimal cut-point for VAT area at the umbilicus level was 111 cm^2 for men and 96 cm^2 for women to identify people with one or more cardiometabolic risk factors, and was 142 cm^2 for men and 115 cm^2 for women for VAT area at the L2/3 level. In addition, VAT area at the L2/3 level had comparable power with VAT area at the umbilicus level to identify people with cardiometabolic risk factors.

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Competing interests

None declared.

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Ethical Approval

The study was approved by the Medical Ethics Committee of [INSTITUTION], and informed consent was obtained from all participants. This research study was conducted in accordance with the guidelines of the Declaration of Helsinki.

Author contributions

LLH, KL and XGC designed the study. KL, WD, LW, LX, PJ and DZ were involved in data collection. LLH analyzed the data and wrote the first draft of the manuscript. KL, WD, JES, DZ and XGC reviewed/edited the manuscript. LW, LX, PJ and DZ were involved in laboratory analyses and quality control. All authors contributed to the interpretation of the results and revision of the manuscript for important intellectual content and approved the final version of the manuscript. XGC and DZ are the guarantors of this work and, as such, had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1. AUC of visceral adipose tissue area and total adipose tissue areas area measured at the L2/3 level and umbilicus level to identify the presence of individual cardiometabolic risk factors.