

## Original Article

# A comparison of ultrasound and magnetic resonance imaging to assess visceral fat in the metabolic syndrome

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Visceral adipose tissue (VAT) plays a key role in the metabolic syndrome. Easy detection of VAT could be an important tool to increase understanding of the metabolic syndrome. To study the relationship between the area of the inferior part of the perirenal fat (AIPPF) and anthropometric, imaging and cardiovascular risk factors of metabolic syndrome, seventy two subjects with metabolic syndrome were recruited including 44 men and 28 women (age:26-68 yr). Each subject underwent ultrasound detection of AIPPF, intraabdominal fat thickness and magnetic resonance imaging (MRI) to calculate abdominal VAT (MRI VAT). Anthropometric and cardiovascular risk factors were also evaluated. AIPPF measured by ultrasonography demonstrated excellent reproducibility. Receiver operating characteristic analysis revealed that AIPPF has the best sensitivity for women, specificity for men and accuracy of the various measures to predict visceral obesity (MRI VAT value  $\geq 110 \text{ cm}^2$ ) for both genders. AIPPF was related to MRI VAT, ultrasound measured intraabdominal fat, waist circumference, the ratio of waist and hip circumferences (of men), body mass index and the main cardiovascular risk factors of metabolic syndrome. Multiple stepwise linear regression analysis suggested that MRI VAT affected AIPPF independent of other investigated obesity indices. This study showed that AIPPF could be applied as an easy and reliable imaging indicator of visceral obesity and cardiovascular risk factors in the metabolic syndrome.

**Key Words:** perirenal fat, ultrasound, visceral adipose tissue, metabolic syndrome, cardiovascular risk factors

## Introduction

The number of people in China with the metabolic syndrome has increased rapidly in recent years.<sup>1</sup> There are no well accepted criteria for the diagnosis of the metabolic syndrome. Nevertheless, it is identified by the presence of three or more metabolic alterations, such as impaired fasting glucose or glucose intolerance, insulin resistance, abdominal obesity, hypertension, high levels of triglycerides, low levels of high-density lipoprotein cholesterol and microalbuminuria.<sup>2</sup> The metabolic syndrome is related to a number of cardiovascular risk factors.<sup>3,4</sup>

Obesity is associated with increased morbidity and mortality, independent of dyslipidemia, diabetes, and hypertension.<sup>5</sup> Though general adiposity, expressed as body mass index (BMI), was significantly correlated with cardiovascular risk factors,<sup>6</sup> intraabdominal fat is probably more important than overall weight as a cardiovascular risk factor.<sup>7,8</sup> According to the new International Diabetes Federation definition, for a person to be defined as having the metabolic syndrome they must first have central obesity (defined as waist circumference  $\geq 94\text{cm}$  for European men and  $\geq 80\text{cm}$  for European women, with ethnicity specific values for other groups).<sup>9</sup> The amount of visceral fat plays

a critical role in the relationships between regional fat distribution and metabolic complications.

In clinical and epidemiologic studies, the estimate of intraabdominal fat that is used most often is waist circumference or the ratio of waist and hip circumferences (WHR). Although these measures showed a good correlation with intra-abdominal fat measured by computed tomography (CT), they are less precise than CT and are strongly associated with BMI.<sup>10</sup> Imaging techniques, like CT and magnetic resonance imaging (MRI) allow a precise and reliable measurement of visceral fat.<sup>11,12</sup> However, these imaging techniques are expensive, not generally available and, in the case of CT, expose subjects to ionizing radiation.

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In research settings, ultrasound measurement has been proposed as a suitable technique to accurately estimate intraabdominal fat (IAF).<sup>13,14</sup> Several studies found a good correlation between thickness of intraabdominal fat measured by ultrasound and amounts measured by CT,<sup>15</sup> but the use of these ultrasonographic measures has been criticized because of their presumed low reproducibility.<sup>16</sup> We recently developed and validated an ultrasound protocol for the assessment of the area of the inferior part of the perirenal fat (AIPPF), which does not have the limitations of CT or MRI measurement. It is an ultrasound measured area of local abdominal visceral fat, while previous ultrasound studies involved only distances or thicknesses. We applied this new technique in a clinical study at our hospital to determine the relationship of AIPPF to anthropometric, imaging and metabolic parameters of metabolic syndrome. This study aims to create a novel method of easily ultrasound measured visceral fat which can predict visceral obesity better than other widely used methods and correlates to cardiovascular risk factors of metabolic syndrom.

## Methods

### Subjects

Seventy two subjects (mongolian, 44 males and 28 females, aged 26 - 68 years) were recruited in the Physical Examination Center in our hospital. The mean age was  $48.96 \pm 9.22$  years. The mean BMI was  $27.56 \pm 2.90$ . Most of them were civil servants, business people, not including farmers or unemployment people. Metabolic syndrome was diagnosed as: hyperglycemia (fasting glucose  $\geq 6.1$  mmol/l) in addition to at least two of the following: ① central obesity [BMI  $\geq 30$ kg/m<sup>2</sup> or WHR (man  $> 0.90$ , women  $> 0.85$ )], ② dyslipidemia [triglycerides  $\geq 1.7$  mmol/l or HDL cholesterol (man  $< 0.9$  mmol/l, women  $< 1.0$  mmol/l)], or ③ hypertension (BP  $\geq 140/90$  mmHg). Subjects who have had antihyperglycemia agents, antihypertensive therapy, lipid lowering therapy and weight-reducing aid or any known severe disease were excluded from the research. This study was approved by an ethics committee for the protection of human subjects and informed consents were obtained from all individuals.

### Anthropometric measurements

Body weight was measured to the nearest 0.05 kg using a digital scale and height was measured to the nearest 0.1 cm using a wall-mounted stadiometer with the subjects wearing indoor clothes. BMI was calculated as weight (kg) divided by height<sup>2</sup> (m<sup>2</sup>). Waist circumference was measured midway between the lower rib margin and the iliac crest and hip circumference was measured at the level of the widest circumference over the great trochanters. Both circumferences were measured at the end of a gentle expiration while subjects were standing. The variability of duplicate measurements in a subsample of the population (n=26) of the waist and hip circumference was 1.2% and 0.8% respectively. After sitting for at least 10 min, blood pressure was measured using a standard mercury sphygmomanometer. The Korotkoff sound V was taken as the diastolic blood pressure; the mean of 2 measurements was used in the analysis.

### Analytical procedures

Venous blood samples were taken and collected in heparinized tubes after an overnight fast to measure: the baseline insulin, glucose, total cholesterol, triglycerides, HDL-cholesterol, LDL-cholesterol, uric acid and CRP concentrations. Samples were centrifugated and commercial enzymatic kits [coefficient of variation (CV) range from  $1.8 \pm 0.2\%$  to  $3.7 \pm 0.5\%$  respectively] were used on a Hitachi 7600 analyzer (Hitachi, Tokyo, Japanese) for analysing. High sensitivity CRP was measured with the use of latex-enhanced immunonephelometric assays on an IMMAGE immunal analyzer with an affiliated agent used specially for Beckman-Coulter (Autoanalyzer, Beckman Coulter, Fullerton, America; CV,  $4.2 \pm 0.5\%$ ). Plasma insulin was measured with the use of chemoluminescence assays on an ACCESS immunal analyzer with an affiliated agent used specially for Beckman Coulter (CV,  $3.1 \pm 0.3\%$ ).

### Ultrasound measurements

Ultrasound measurements were performed with a HDI 5000 SonoCT (Philips Medical Systems, Eindhoven, Netherlands) with an abdominal (C 5-2 40R 2-5 MHz) curvilinear transducer. The subjects were lying in a supine position, the transducer was placed between the midaxillary line and postaxillary line, paralleling with the long axis of the kidney. The kidney and its adipose capsule surrounding it moved with breathing while the pararenal fatty body and other tissue around the perirenal fat kept at rest. After seeing the board of the adipose capsule, the sonographer froze the picture, drew a straight line tangent to the inferior pole of the kidney and encircled the inferior part of the perirenal fat. This tangent line is vertical to the long axis of kidney. The mean value of the bilateral area calculated by the software of the system was AIPPF for analyzing (Fig 1). If air in the colon blocked the ultrasonic waves the sonographer moved the transducer toward the postaxillary line a little and pressed inward slightly to get a clearer image. The mean value of 3 measurements was then used in the analysis. No samples were excluded because the view was unsatisfactory.

In making the ultrasound measurements of intraabdominal fat (US IAF), we used the distance between the



**Figure 1.** The area encircled in the dash line is the area of the inferior part of the perirenal fat (AIPPF), the value is marked at the bottom left.

peritoneum and the lumbar spine. A strict protocol, including the position of and pressure on the transducer, was used. All measurements were performed at the end of a quiet inspiration. Each distance was measured at 3 positions, and each measurement was performed three times. The vertebral column was positioned horizontally. The measurements were done without distortion (by compression) of the abdominal cavity.<sup>15</sup> With this protocol, we excluded 3 subjects from 72 initially selected because air in the colon blocked the ultrasonic waves.

To determine the reliability of the ultrasound measurements two sonographers independently examined 18 of the 72 subjects. One has 5 years experience while the other has 15 years experience of sonography work. They did not have knowledge of other operator's scanning results. The measurements of AIPPF and IAF were made by each sonographer with the above-mentioned procedure.

### MRI measurements

MRI scans were performed with a whole-body scanner (GYROSCAN S15, Philips Medical Systems, Best, The Netherlands) using a 1.5 T magnetic field (64 MHz) and an inversion recovery pulse sequence (inversion time 300 ms, repetition time 820 ms, and echo time 20 ms). Slice thickness was 10 mm. The performance of one measurement took 10 min. One single transverse scan was taken halfway between the lower rib margin and the iliac crest with the subject lying supine. This site was determined by palpation and the location was about on the L4-L5 vertebra.<sup>12</sup> The intraclass correlation coefficient for repeated VAT area determinations in our laboratory was 0.95. In this study, MRI VAT value more than 110 cm<sup>2</sup> was regarded as the cutoff value for visceral obesity.

### Statistical analyses

Data in the text and tables are expressed as mean  $\pm$  SD. Differences between men and women and results between the two sonographers were tested with the Student's *t* test. Pearson correlation analysis was used to analyze relationships between AIPPF and other investigated variables. Receiver operating characteristic (ROC) analysis was used to assess the specificity and sensitivity of the various measures. Optimal cutoff points were determined by visually assessing, which score combined maximum sensitivity and specificity. The area under the ROC curve was a measure of the accuracy of a model, such that the higher the area, the more accurate was the model. Stepwise regression analysis was performed on the investigated obesity indexes to determine their independent relationships to AIPPF, and variables found to be  $p < 0.1$  by univariate analysis were entered into a multiple stepwise linear regression analysis. Male and female subjects were separately analyzed. Two-tailed  $p < 0.05$  indicated statistical significance. All analyses were performed using the Statistical Package for the Social Sciences (SPSS) for Windows, version 9.01 (SPSS Inc, Chicago).

### Results

#### Subject characteristics

The main anthropometric, imaging and clinical characteristics of the subjects studied are summarized in Table 1. Except US IAF, HDL-C and plasma uric acid, there were no significant differences in other parameters between men and women.

#### Ultrasound measurements

AIPPF measurements were executed in all 72 consecutive

**Table 1.** Anthropometric, imaging and cardiovascular risk factors in men and women with metabolic syndrome

	Men(n=44)	Women(n=28)	<i>p</i> value
Age (yr)	48.6 $\pm$ 9.8	49.7 $\pm$ 8.4	0.614
Waist (cm)	95.5 $\pm$ 8.9	96.2 $\pm$ 7.6	0.758
BMI (kg/m <sup>2</sup> )	27.1 $\pm$ 2.9	28.3 $\pm$ 2.7	0.096
MRI VAT(cm <sup>2</sup> )	113.1 $\pm$ 15.9	111.9 $\pm$ 15.1	0.737
AIPPF(cm <sup>2</sup> )	10.5 $\pm$ 3.0	9.6 $\pm$ 2.4	0.155
US IAF(cm)	10.3 $\pm$ 0.9	9.6 $\pm$ 0.8	0.002
WHR	0.96 $\pm$ 0.05	0.98 $\pm$ 0.07	0.109
Syst BP (mm Hg)	136.7 $\pm$ 11.7	133.0 $\pm$ 7.8	0.138
Diast BP (mm Hg)	85.0 $\pm$ 6.1	85.3 $\pm$ 6.3	0.867
Glucose (mg/dl)	6.3 $\pm$ 0.9	6.4 $\pm$ 0.8	0.706
Insulin (IU/ml)	15.6 $\pm$ 9.2	14.9 $\pm$ 11.5	0.772
Total cholesterol(mmol/l)	5.4 $\pm$ 1.0	5.6 $\pm$ 0.8	0.377
LDL-C(mmol/l)	3.4 $\pm$ 0.9	3.2 $\pm$ 0.9	0.510
HDL-C(mmol/l)	1.0 $\pm$ 0.2	1.2 $\pm$ 0.3	0.032
Triglycerides (mmol/l)	3.4 $\pm$ 2.4	3.2 $\pm$ 1.6	0.592
Uric acid(mg/dl)	6.8 $\pm$ 2.1	5.6 $\pm$ 2.1	0.017
CRP (mg/dl)	3.7 $\pm$ 1.9	2.9 $\pm$ 2.4	0.118

Data are presented as mean  $\pm$  SD; Waist = waist circumference, BMI = body mass index, MRI VAT = magnetic resonance imaging measured visceral adipose tissue, AIPPF = the area of the inferior part of the perirenal fat, US IAF = ultrasound measurements of intraabdominal fat, WHR = the ratio of waist and hip circumferences, Syst BP = systolic blood pressure, Diast BP = diastolic blood pressure, Glucose = fasting glucose, Insulin = fasting insulin, HDL-C = high density lipoprotein cholesterol, LDL-C = low density lipoprotein cholesterol, CRP = cross-reacting protein.

**Table 2.** The relationship between AIPPF and related physiology and anatomy parameters

	<i>r</i>	<i>p</i>
Age	0.146	0.220
Height	0.019	0.876
Weight	0.316	0.008
Length of the kidney	-0.062	0.607
Width of the kidney	0.110	0.359

AIPPF = the area of the inferior part of the perirenal fat.

subjects, while 3 subjects (4.2%) failed in IAF measurement for the interference of air in the intestinal tract. The mean value of bilateral AIPPF ranged from 5.6 cm<sup>2</sup> to 19.1 cm<sup>2</sup>, the left side was a bit larger than the right side (10.5 ± 2.9 cm<sup>2</sup> vs. 9.8 ± 2.8 cm<sup>2</sup>, *p* < 0.001). There was no relationship between AIPPF and age, height, length or width of the kidney (mean value of bilateral kidney), except weight (*p* = 0.008) (Table 2). The ultrasound measurements of different fat deposits showed good interoperator (*t* = -0.083, *p* = 0.433 for AIPPF; *t* = -0.848, *p* = 0.408 for US IAF) and intraoperator (*t* = 0.358, *p* = 0.725 for AIPPF; *t* = -0.629, *p* = 0.537 for US IAF) reliability.

#### Receiver operating characteristic (ROC) analysis

The ROC analysis revealed that AIPPF might have the best sensitivity for women, specificity for men and accuracy of the various measures to predict visceral obesity (MRI VAT value ≥ 110 cm<sup>2</sup>) for both genders. The optimal cutoff points of AIPPF for men and women were 11.1 cm<sup>2</sup> and 8.8 cm<sup>2</sup> respectively. The corresponding sensitivities to predict visceral obesity were 81.8% for men and 92.3% for women, and the specificities were 95.0% and 78.6% respectively. For men, the area under the curve (AUC) of AIPPF was 0.886 (95% CI 0.771 to 1.00, *p* < 0.001) and it might be higher than the AUC of waist circumference 0.816 (95% CI 0.690 to 0.941, *p* < 0.001), BMI 0.836 (95% CI 0.716 to 0.956, *p* < 0.001) and US IAF 0.778 (95% CI 0.641 to 0.916, *p* = 0.002). For women, the AUC of AIPPF was 0.923 (95% CI 0.827 to 1.02, *p* < 0.001) and it might be higher than the AUC of waist circumference 0.871 (95% CI 0.719 to 1.023, *p* = 0.001), BMI 0.852 (95% CI 0.692 to 1.01, *p* = 0.002) and US IAF 0.874 (95% CI 0.726 to 1.02, *p* = 0.001). WHR

could not predict visceral obesity for both men (*p* = 0.314) and women (*p* = 0.216) (Table 3).

#### Anthropometric, imaging and cardiovascular risk factors correlates of AIPPF

In a Pearson correlation analysis, AIPPF showed excellent correlations with MRI VAT in both genders and waist circumference, US IAF, plasma insulin of men (*p* < 0.001). AIPPF was also related to BMI, plasma total cholesterol, LDL-C, CRP and blood pressure in both genders; WHR, plasma blood glucose and uric acid of men; and waist circumference (*p* = 0.001), US IAF (*p* = 0.001) of women. For both genders, no correlation between age, HDL-C, triglyceride and AIPPF was found (Table 4). For the total samples, AIPPF was also correlated with MRI VAT excellently (*r* = 0.768, *p* < 0.001, Fig. 2).

Multiple stepwise regression analysis confirmed that in both genders, MRI VAT was the only one independent variable among the investigated obesity indexes related to AIPPF and it explained 59.0% (of men, *t* = 7.582, *p* < 0.001, standardized coefficients = 0.768, *R*<sup>2</sup> = 0.590) to 62.3% (of women, *t* = 6.424, *p* < 0.001, standardized coefficients = 0.789, *R*<sup>2</sup> = 0.623) of the variances of AIPPF.

#### Discussion

The results of this study showed that AIPPF measured by ultrasonography has an excellent reproducibility and it did not be affected by age, gender, height and length or width of the kidney. Though perirenal fat has been previously involved in visceral fat research,<sup>14</sup> it is the first time to study the clinical significance of the area of part of the perirenal fat. For both genders, the ROC analysis revealed that AIPPF might have the best sensitivity, specificity and accuracy of the various measures to predict visceral obesity (MRI VAT value ≥ 110 cm<sup>2</sup>). AIPPF was related to MRI VAT, waist circumference, WHR (of men), BMI, US IAF and the main cardiovascular risk factors of metabolic syndrome. To identify which of the investigated obesity indexes affected AIPPF independently, multiple stepwise linear regression analysis were applied for the both genders. It showed that MRI VAT affected AIPPF independent of other investigated obesity indexes. It

**Table 3.** Receiver operating characteristic (ROC) analysis of the efficiency of various obesity indexes to predict visceral obesity

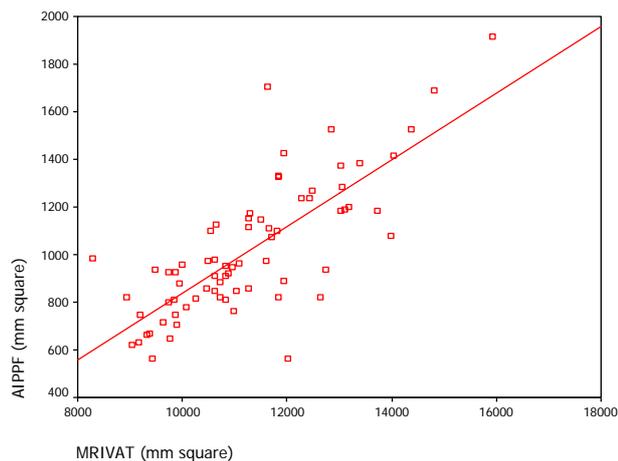
	Men					Women				
	Cutoff value	Sensitivity (%)	Specificity (%)	AUC	95%CI	Cutoff value	Sensitivity (%)	Specificity (%)	AUC	95%CI
AIPPF	11.1 cm <sup>2</sup>	81.8	95.0	0.886 ± 0.059	0.771 to 1.00	8.8 cm <sup>2</sup>	92.3	78.6	0.923 ± 0.049	0.827 to 1.02
Waist	95.0 cm	77.0	65.0	0.816 ± 0.064	0.690 to 0.941	93.5 cm	84.6	73.4	0.871 ± 0.075	0.719 to 1.02
BMI	26.6	72.7	80.0	0.836 ± 0.061	0.716 to 0.956	28.4	84.6	85.7	0.852 ± 0.081	0.692 to 1.01
USIAF	95.5 mm	90.9	50.0	0.778 ± 0.070	0.641 to 0.916	99.5 mm	76.9	100	0.874 ± 0.075	0.726 to 1.02
WHR†	0.925	81.8	25.0	0.591 ± 0.089	0.416 to 0.766	0.935	92.3	45.7	0.640 ± 0.109	0.426 to 0.854

Visceral obesity: MRI VAT value more than 110 cm<sup>2</sup>; †: *p* = 0.314 for men and *p* = 0.216 for women; AUC = area under ROC curve, data are presented as the mean ± SD; 95%CI = 95% confidence intervals of area under ROC curve

**Table 4.** Pearson correlation analysis for the relationships between AIPPF and other investigated obesity indices and cardiovascular risk factors

	Men (n = 44)		Women (n = 28)	
	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>
MRI VAT	0.770	< 0.001	0.788	< 0.001
Waist	0.681	< 0.001	0.592	0.001
US IAF	0.630	< 0.001	0.610	0.001
BMI	0.455	0.002	0.388	0.041
WHR	0.354	0.018	0.362	0.058
Age	0.157	0.308	0.64	0.405
Glucose	0.318	0.035	0.076	0.701
Insulin	0.529	< 0.001	0.588	0.001
TG	0.089	0.565	-0.178	0.364
TC	0.328	0.030	0.410	0.030
HDL-C	-0.075	0.628	0.232	0.236
LDL-C	0.324	0.032	0.434	0.021
Syst BP	0.368	0.014	0.404	0.033
Diast BP	0.398	0.007	0.554	0.002
CRP	0.350	0.020	0.463	0.013
Uric acid	0.422	0.004	0.329	0.087

TC = Total cholesterol, TG = Triglycerides; The other abbreviations are the same as Table 1.



**Figure 2.** Scatter plot of the area of the inferior part of the perirenal fat (AIPPF) vs. MRI VAT of the total samples (n = 72,  $r = 0.768$ ,  $p < 0.001$ ); MRI VAT = magnetic resonance imaging measured visceral adipose tissue

suggests that AIPPF measured by ultrasonography could be a good parameter to predict MRI VAT or visceral obesity.

Perirenal fat is in the retroperitoneum and deposited around the two kidneys. The inferior part of perirenal fat contains the most affluent fat of the whole perirenal fat. Our data showed that the accuracy of AIPPF predicting visceral obesity might be better than other investigated obesity indexes and it had an excellent correlation with MRI VAT. The possible common pathway during embryogenesis could explain this finding. In fact, in their infancy perirenal fat and intraabdominal fat seem to be originally in the brown adipose tissue. Brown adipocyte diminished with growth and white adipocyte which reserves energy replaced them. In adults, there are few brown adipocytes in the perirenal fat. Though waist circumference and WHR are widely used in estimating intraabdominal fat in clinical and epidemiologic studies,

these measures are less precise than CT and are strongly associated with BMI.<sup>10</sup> It is probably due to the single waist circumference or WHR cannot distinguish subcutaneous fat from intra-abdominal fat.<sup>17</sup> Our data showed that AIPPF was affected by MRI VAT independent of waist circumference or WHR. This may due to that the perirenal fat contains only visceral adipose tissue while the single waist circumference or WHR cannot distinguish subcutaneous fat from intraabdominal fat.

There is now growing evidence showing that visceral fat may be the culprit of metabolic syndrome. Compared to subcutaneous fat, visceral fat contains more  $\beta$ -adrenergic receptors, especially  $\beta_3$ - receptors. Therefore, visceral adipocytes are more sensitive to the lipolytic effects of catecholamines and are more resistant to the antilipolytic effects of insulin, leading to increased free fatty acid production. The latter may lead to reduced fat acid oxidation and ectopic fat deposition in the muscle and liver which worsens insulin resistance by reducing peripheral glucose uptake.<sup>18</sup> Besides, visceral adipocytes secrete many cytokines and vasoactive peptides including interleukin-6, tumour necrosis factor- $\alpha$ , angiotensin- $\text{II}$ , plasminogen activator inhibitor- I, etc which have direct effects on the vascular to increase cardiovascular risk.<sup>19,20</sup> The correlations of insulin, plasma glucose, total cholesterol, LDL cholesterol, uric acid, arterial blood pressure and CRP with AIPPF in our subjects seems to support these observations. The excellent relationship of AIPPF to plasma insulin levels (for men,  $p < 0.001$ ; for women  $p = 0.001$ ) strongly suggests that it should be considered a highly insulin-resistant adipose tissue.

In the past few years, several scholars have observed the clinical significance of detecting local visceral adipose tissue. It was reported that epicardial adipose tissue was related to MRI VAT, waist circumference, BMI, fat mass and cardiovascular risk factors of metabolic syndrome.<sup>21,22</sup> Mesenteric fat thickness was considered as an independent determinant of all components of metabolic syndrome. Its relationships with some of the cardiovascular risk factors could be better than ultrasound measurement of subcutaneous and preperitoneal fat thickness, MRI measurement of total VAT and anthropometric indexes.<sup>23</sup> It could identify subjects with increased carotid intima-media thickness.<sup>24</sup> Stolk et al (2003) reported that ultrasound measurements of intraabdominal fat estimated the metabolic syndrome better than do measurements of waist circumference.<sup>25</sup> Onji et al (2005) combined the detection of the fat layer of the posterior right renal wall and other distance in abdominal and found a combined equation that can predict VAT measured by CT.<sup>14</sup> In all these studies, the distances or thicknesses, but not area were investigated. We suppose they must have certain limitations to predict total visceral fat area or volume. In this study, we used a mean value for the bilateral area but not the distance detected by ultrasound to predict VAT, which was the important difference between this and others' studies. That AIPPF predicted visceral obesity better than US IAF for both genders in this study suggests that the detection of AIPPF may be an improvement of ultrasound measurements of visceral fat.

Thus, this study recommended a new and convenient method for visceral obesity prediction. The detection is

not affected by air and chymus in the intestinal tract; the shape of the perirenal fat will not be distorted by the pressure of a transducer. Moreover, this study confirmed that a junior sonographer can be as successful as a senior sonographer. As a relatively cheap, noninvasive and technically less demanding ultrasound method with good reproducibility, the ultrasound measurement of AIPPF could potentially become an useful imagine tool for metabolic syndrome research. It can be also be applied in evaluating the efficiency of weight loss treatment for the fact that visceral fat usually shows greater responses than subcutaneous fat to interventional therapy such as changes in caloric intake or physical exercise.

In conclusion, the ultrasound detection of AIPPF is a potential method to predict visceral obesity; MRI VAT affected AIPPF independent of other investigated obesity indices. Findings from this small study will need to be confirmed in prospective studies involving larger populations with different demographic features and cardiovascular risk profiles.

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