



# Assessment of body compositions in the prediction of metabolic syndrome in adults

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**Background:** The musculoskeletal system participates in the pathology of metabolic disorders. Several studies have focused on body composition changes; however, the adipose tissue between muscle bundles with different metabolic statuses has rarely been studied. This study sought to explore the association between body compositions and metabolic disorders in Asians, and identify whether these body compositions can be used to detect metabolic disorders with different waist circumferences (WCs) by computed tomography (CT).

**Methods:** A total of 116 subjects were included in the study and categorized into the following four groups according to WC and metabolic syndrome (MS): (I) the healthy control group; (II) the normal WC with metabolic disorder group; (III) the normal WC with MS group; and (IV) the larger WC with MS group. The International Diabetes Federation (IDF) criteria based on WC, laboratory tests, body mass index (BMI), and medical history was used to diagnose MS. Body composition parameters, such as muscle attenuation, the cross-sectional area of subcutaneous adipose tissue (SAT), muscle, extramyocellular lipid (EMCL), visceral adipose tissue (VAT), and the ratios between different compositions [e.g., the SMR (SAT/muscle), EMR (EMCL/muscle), and VMR (VAT/muscle)] were calculated for the thigh and abdomen. The areas under the curve (AUCs) of the receiver operating characteristic (ROC) curves adjusted for multiple comparisons were used to discriminate among metabolic disorders.

**Results:** The groups with metabolic disorders had more SAT ( $P=0.001$ ) and EMCL ( $P=0.040$ ) in the thigh, and more VAT ( $P=0.001$ ) and a higher SMR ( $P<0.001$ ) in the abdomen. EMCL and muscle attenuation in the thigh (AUCs =0.790 and 0.791), and the VMR and SMR in the abdomen were better able to diagnose metabolic disorders (AUCs =0.752 and 0.746) than other body composition parameters. While SAT and EMCL in the thigh (AUCs =0.768 and 0.760), and VAT and the VMR in the abdomen (AUCs =0.788 and 0.775) were better able to diagnose MS than other parameters.

**Conclusions:** Body composition parameters for the thigh and abdomen could assist in detecting patients with an increased risk of MS.

**Keywords:** Subcutaneous adipose tissue (SAT); extramyocellular lipid (EMCL); muscle; metabolic syndrome (MS); computed tomography (CT)

Submitted Dec 03, 2023. Accepted for publication Jun 21, 2024. Published online Jul 23, 2024.

doi: 10.21037/qims-23-1724

View this article at: <https://dx.doi.org/10.21037/qims-23-1724>

## Introduction

Metabolic syndrome (MS) consists of several metabolic abnormalities, including elevated blood pressure, insulin resistance, a hypercoagulable state, dyslipidemia, and a proinflammatory state (1). Patients with MS have an increased risk of atherosclerotic cardiovascular disease and type 2 diabetes (2). The musculoskeletal system disorders may occur under MS conditions, such as insulin resistance and sarcopenia (3-5). Evidence suggests that body compositions play an important role in the pathophysiology of MS and are involved in fat oxidation in muscle and adipose tissue lipolysis (6). Research has also shown that inflammatory cytokines exert a significant influence on cardiovascular diseases in metabolic disorders (7).

Adipose tissue and skeletal muscle have been used as biomarkers of chronic metabolism diseases in research and clinical practice. In metabolism-related diseases, the assessment of regional fat distribution is more important than the body mass index (BMI) (8), or the total fat content (9). In MS, ectopic fat accumulates in the skeletal muscle and visceral organs, including the liver, heart, and visceral adipose tissue (VAT) (10). Muscle mass in the thigh has been shown to be an indicator of cardiovascular health-related metabolic disorders (11). Increased VAT is associated with a higher risk of cardiovascular disease (12). The BMI can reflect the obesity of the whole body but cannot be used to evaluate metabolic risks. Extramyocellular lipid (EMCL) between muscle bundles is thought to be an indicator of muscle metabolism (13) and muscle quality. Further, EMCL and muscle mass have been shown to be related to amyotrophy (14,15).

The waist circumference (WC) is related to the BMI and is thought to be a symbol of central obesity (16,17). However, even patients with a normal WC and BMI may suffer from metabolic disorders (8,18). There are many modalities for assessing body compositions, such as magnetic resonance imaging, computed tomography (CT) and dual-energy X-ray absorptiometry. CT has been used as the standard reference in body composition analyses according to different attenuation characteristics of the tissues and has been shown to have high resolution and efficiency (19,20).

In this study, we aimed to explore the association between metabolic disorders and body compositions in Asians, and determine whether body compositions can be used to detect metabolic disorders with different WCs in CT images. We present this article in accordance with the STROBE reporting checklist (available at <https://qims.amegroups.com/article/view/10.21037/qims-23-1724/rc>).

## Methods

This single-center, retrospective study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Institutional Review Board of the Tongji Hospital (TJ-IRB20210602), and the requirement of informed consent for this retrospective analysis was waived.

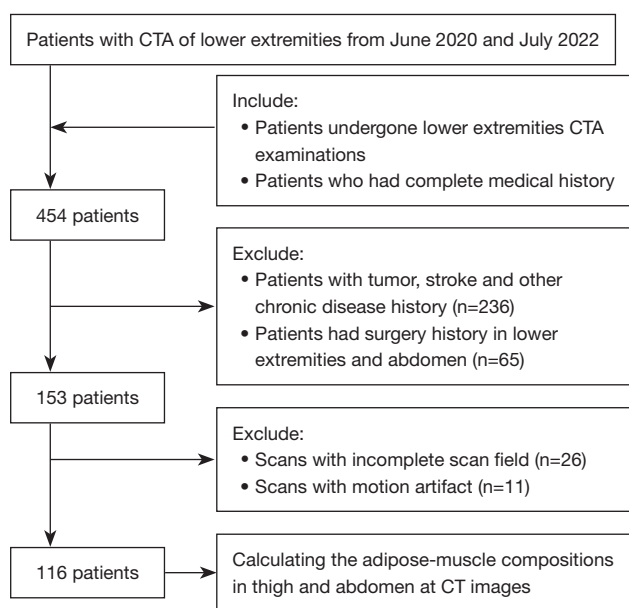
### Subjects

Patients at Tongji Hospital who underwent CT examinations of lower extremities between June 2020 and July 2022 with a complete medical history and high-quality images were included in the study. To be eligible for inclusion in this study, the patients had to meet the following inclusion criterion: have careful medical recordings and have undergone complete systematic assessments [e.g., laboratory and anthropometric examinations, and blood pressure, plasma triglycerides, and high-density lipoprotein cholesterol (HDL-C) tests]. Patients were excluded from the study if they met any of the following exclusion criteria: had experienced a trauma or had undergone surgery in the abdomen or thigh (e.g., amputation and arthroplasty); had congenital muscular atrophy; had a chronic disease affecting muscle mass, such as tuberculosis, cancer, stroke; and/or had uncomplete medical records or poor-quality images. The study flowchart is displayed in *Figure 1*.

The subjects included in this study were mostly from the Internal Medicine Department of Tongji Hospital, and were suspected to have metabolic disorders, such as diabetes or dyslipidemia; however, some had attended the hospital to undergo health examinations. The patients included in the study were divided into the following four groups according to their WC and the presence of an MS: Group 1, which comprised healthy control patients with normal WCs and no MS risk factors; Group 2, which comprised patients with normal WCs and metabolic disorders (one or two metabolic risk factors: either diabetes, hypertension, or hyperlipidemia); Group 3, which comprised patients with normal WCs and MS; and Group 4, which comprised patients with larger WCs and MS.

### MS diagnosis criteria

MS was diagnosed based on the International Diabetes Federation (IDF) criteria (21,22) as follows: an ethnicity specific WC (see below) or a BMI >30 kg/m<sup>2</sup>, plus ≥2 other



**Figure 1** Study flowchart. CTA, computed tomography angiography; CT, computed tomography.

of the following criteria: fasting plasma glucose  $\geq 5.6$  mmol/L (100 mg/dL) or a previous diagnosis of type 2 diabetes mellitus (an oral glucose tolerance test is also strongly recommended but not necessary); blood pressure  $\geq 130/80$  mm Hg, or treatment of previously diagnosed hypertension; plasma triglycerides  $\geq 1.7$  mmol/L (150 mg/dL), or specific treatment for hypertriglyceridemia; HDL-C of  $<1.03$  mmol/L (40 mg/dL) for males or  $<1.29$  mmol/L (50 mg/dL) for females, or specific treatment for low HDL-C. In relation to the ethnicity specific WC, the criteria were as follows: a WC  $\geq 94$  cm for male or  $\geq 80$  cm for female Europeans; a WC  $\geq 90$  cm for male or  $\geq 80$  cm for female South Asians; a WC  $\geq 90$  cm for male or  $\geq 80$  cm for female Chinese; or a WC  $\geq 85$  cm for male or  $\geq 90$  cm for female Japanese.

### Image analysis

The CT images were obtained using CT scanners manufactured by Toshiba (Toshiba Medical Systems, Otawara, Japan). The following parameters were used for the CT scans: tube voltage: 80 kVp; slice thickness: 1 mm; tube current: 145 mA; and in-plane pixel range:  $0.656 \times 0.656 - 0.832 \times 0.832$  mm<sup>2</sup>.

Subcutaneous adipose tissue (SAT) was separated, fascia, bone, and vessels were excluded semi-automatically with manual corrections on the CT images. Adipose tissue

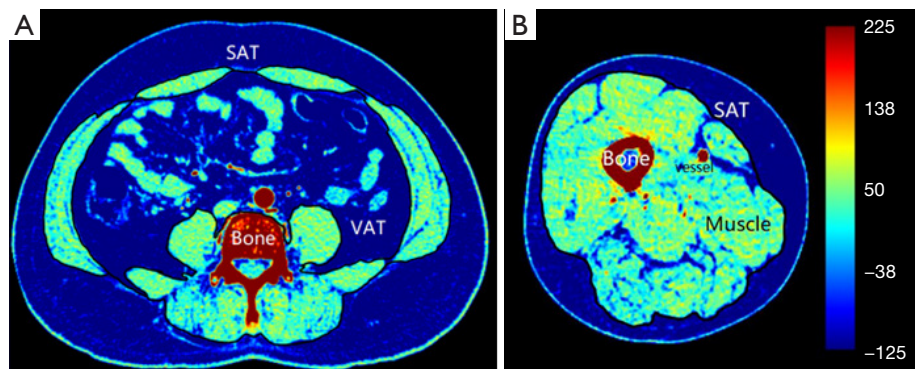
distributed between the muscle bundles was defined as EMCL (23). Visceral fat was outlined by the abdominal muscular and viscera organs in the abdomen. The cross-sectional areas of the adipose (SAT, VAT, and EMCL) and skeletal muscles (abdomen: the sum of the abdominal oblique, the rectus abdominis, psoas muscles, and erector spinae; thigh: mainly the sum of the hamstrings and quadriceps femoris) were measured. The measurement of body compositions was based on the Hounsfield unit (Hu) (muscle: 50 to 80 Hu, SAT:  $-80$  to  $-150$  Hu, and EMCL:  $-60$  to  $-150$  Hu) at the mid-thigh and L4 vertebra level. In the abdomen, the cross-sectional areas of the muscle and adipose tissue were calculated in continuous slices at the L4 vertebrate level, and the sum of the measurements were divided by the slice number. The measurement of the mid-thigh was similar to that of the abdomen with the additional average of the left and right thighs. The cross-sectional area was divided by the height square to reduce the bias. The following ratios between the adipose and muscle were calculated: the SAT/muscle ratio (SMR), the VAT/muscle ratio (VMR), and the EMCL/muscle ratio (EMR). The HU values of the muscle in the thigh and abdomen in the CT images were also calculated.

The muscle, SAT, and EMCL were separated based on HU thresholds and anatomy. All the measurements were performed using ImageJ (version 1.53, National Institutes of Health, Bethesda, MD, USA) and FireVoxel software (Department of Radiology, New York University, USA). The tissue separation illustration is displayed in *Figure 2*.

### Statistical analysis

The statistical analysis was performed using SPSS (IBM, Chicago, USA). The chi-squared test and Kruskal-Wallis test were used to assess differences in the anthropological results, laboratory examinations, and body compositions among the groups. Post-hoc multiple comparisons were performed using the Kruskal-Wallis test and chi-squared test with Bonferroni correction.

A logistic regression analysis with MS and metabolic disorders as the dependent variables after the adjustment of clinical parameters (e.g., age and weight) was performed to examine the relationship between metabolic disorders and body compositions. The area under the curve (AUC) obtained from the receiver operating characteristic (ROC) curve analysis was calculated as a discriminative performance characteristic. The DeLong test was used to compare the AUCs among the different models. The two-



**Figure 2** Illustration of the measurement at the L4 vertebra and mid-thigh in the CT images for a body composition assessment (BMI =20.24 kg/m<sup>2</sup>). Adipose tissue (blue) distributed in the subcutaneous, visceral and intermuscular regions; muscles represented by the green areas. SAT, subcutaneous adipose tissue; VAT, visceral adipose tissue; CT, computed tomography; BMI, body mass index.

**Table 1** Demographic data of the Asian participants in this study

Parameters	Group 1	Group 2	Group 3	Group 4	P
Sex (F, M)	5, 17	12, 27	11, 25	9, 10	0.392
Age (years)	50.76 (17.23)	57.32 (15.48)	63.2 (9.8)	62.74 (14.39)	0.023*
Height (meters)	1.65 (0.07)	1.66 (0.10)	1.65 (0.08)	1.67 (0.08)	0.619
Weight (kg)	59.24 (14.72)	64.53 (13.79)	66.48 (12.22)	75.19 (13.90)	0.016*
Systolic pressure (mmHg)	122.77 (13.90)	126.67 (20.77)	139.8 (19.54)	138.84 (27.06)	<0.001*
Diastolic pressure (mmHg)	80.23 (11.12)	79.44 (13.56)	80.89 (8.37)	84.47 (11.98)	0.001*
Waist circumference (cm)	79.53 (11.81)	82.49 (9.22)	87.69 (6.87)	105.94 (6.68)	<0.001*
HDL-C (mmol/L)	1.10 (0.42)	1.08 (0.33)	0.95 (0.18)	0.91 (0.27)	0.157
Plasma triglycerides (mmol/L)	1.25 (1.03)	1.17 (0.80)	2.16 (1.05)	2.30 (1.22)	<0.001*
Diabetes history	0 (0%)	35 (89.7%)	27 (75%)	14 (73.68%)	<0.001*
Smoke history	5 (22.7%)	12 (30.8%)	16 (44.4%)	4 (21.1%)	0.211
Hypertension history	0 (0%)	13 (33.3%)	25 (69.4%)	11 (57.9%)	<0.001*

Data are presented as the n (%), or the median (interquartile range). \*, there was a significant difference between groups,  $P < 0.05$ . Group 1: healthy control subjects with a normal WC and non-MS risk factors. Group 2: subjects with a normal WC and metabolic disorders. Group 3: subjects with a normal WC and MS. Group 4: subjects with a larger WC and MS. F, female; M, male; HDL-C, high-density lipoprotein cholesterol; WC, waist circumference; MS, metabolic syndrome.

sided (double-tailed) P value for significance was set at 0.05.

## Results

### Demographic and clinical characteristics

A total of 116 Asian patients (of whom 79 were male) were included in this study. The patients were allocated to the different groups according to WC and MS. Age ( $P = 0.023$ ), plasma triglycerides ( $P < 0.001$ ), hypertension ( $P < 0.001$ ), and

diabetes history ( $P < 0.001$ ) differed significantly among the groups. However, no significant differences were observed in terms of sex, height, HDL-C, and smoking history among the different groups. The statistical results of the anthropological and laboratory parameters are set out in *Table 1*.

### Evaluation of body compositions

There were differences among groups in the following body composition parameters: SAT ( $P = 0.001$ ), EMCL ( $P = 0.04$ ),

**Table 2** Measurement of body compositions of thigh and abdomen in different groups

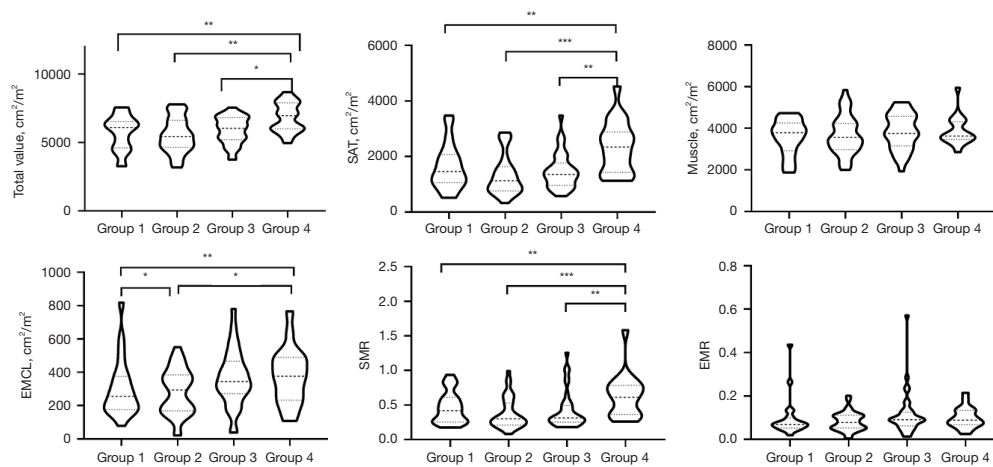
Parameters (adjusted)	Group 1	Group 2	Group 3	Group 4	P
<b>Thigh (cm<sup>2</sup>)</b>					
Total area	5,715.59±1,272.61	5,526.90±1,269.66	5,890.79±986.87	6,816.67±1,076.04	0.005*
Muscle	3,572.79±848.31	3,672.61±935.83	3,830.87±865.28	3,864.34±694.97	0.612
SAT	1,620.96±810.65	1,326.81±711.61	1,478.88±641.48	2,344.63±937.53	0.001*
EMCL	305.08±174.522	284.63±135.33	441.21±475.06	378.60±167.83	0.040*
SMR	0.465±0.23	0.379±0.22	0.420±0.27	0.630±0.31	0.004*
EMR	0.097±0.09	0.082±0.043	0.140±0.25	0.100±0.05	0.289
Mean	62.36±7.92	57.15±8.64	57.83±8.02	43.11±16.77	0.006*
Median	65.56±7.45	58.67±8.32	59.9±8.05	50.27±9.41	0.009*
SD	21.70±5.49	23.24±4.14	23.26±3.87	27.59±5.94	0.003*
<b>Abdomen (cm<sup>3</sup>)</b>					
VAT	2,775.72±2,173.01	3,055.03±2,501.85	4,022.32±1,792.23	5,525.74±2,703.07	0.001*
SAT	4,653.02±1,933.62	4,751.03±2,311.97	5,736.08±2,178.60	9,256.25±3,680.43	<0.001*
Muscle	4,295.60±1,025.30	4,097.69±1,100.65	4,211.12±775.47	4,121.23±928.57	0.772
EMCL	107.43±45.90	109.76±54.15	112.21±66.22	151.74±99.14	0.502
SVR	2.75±1.84	2.62±2.06	2.02±2.71	2.52±2.39	0.137
SMR	1.18±0.53	1.18±0.56	1.39±0.56	2.39±1.21	<0.001*
VMR	1.13±0.65	1.51±1.24	1.92±0.92	2.74±1.54	<0.001*
EMR	0.03±0.01	0.03±0.02	0.03±0.02	0.04±0.03	0.639
Mean	58.85±10.87	54.10±9.26	51.10±9.00	36.98±16.08	0.006*
Median	59.88±11.00	55.6±8.61	52.80±8.75	40.09±14.64	0.008*
SD	19.42±3.97	17.98±4.53	19.81±3.21	25.58±7.42	0.009*

Data are presented as the mean ± SD. \*, there was a significant difference between groups, P<0.05. Group 1: healthy control subjects with a normal WC and non-MS risk factors. Group 2: subjects with a normal WC and metabolic disorders. Group 3: subjects with a normal WC and MS. Group 4: subjects with a larger WC and MS. SAT, subcutaneous adipose tissue; EMCL, extramyocellular lipid; SMR, SAT/muscle ratio; EMR, EMCL/muscle ratio; SD, standard deviation; VAT, visceral adipose tissue; SVR, SAT/VAT ratio; VMR, VAT/muscle ratio; WC, waist circumference; MS, metabolic syndrome.

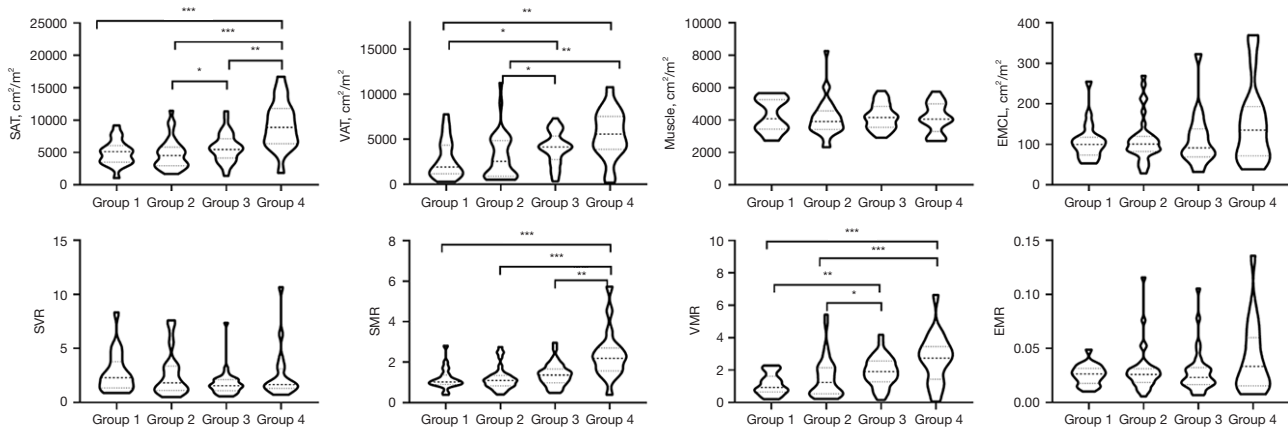
and the SMR (P=0.004) in the thigh. SAT (P<0.001) and VAT (P=0.001), the SMR (P<0.001), and the VMR (P<0.001) were found statistically different between groups in the abdomen. The SMR (P<0.001) and VMR (P<0.001) were significantly different between groups. The HU of muscle in the thigh and abdomen were compared, and the mean (P=0.006 and 0.006) and median value (P=0.009 and 0.008) of the thigh and abdomen were significantly different between groups, and there was a significant difference in the standard deviation (SD) assessment between the groups (P=0.003 and 0.009). For further details, see *Table 2* and *Figures 3,4*.

### **Regression analysis of body compositions and metabolic disorders**

Using metabolic disorders as the independent variables, EMCL (AUC =0.790, sensitivity: 64.13%, specificity: 77.27%) and mean attenuation value of muscle (AUC =0.791, sensitivity: 86.54%, specificity: 77.78%) performed better than other body composition parameters in the thigh. The VMR (AUC =0.752, sensitivity: 73.02%, specificity: 75.00%) and SMR (AUC =0.746, sensitivity:75.28%, specificity: 75.00%) model was better than other parameters in the determination of metabolic disorders in the abdomen.



**Figure 3** The body composition results for the thigh between the groups categorized by the WC and presence of MS. Post-hoc multiple comparisons were made with Bonferroni corrections using the Kruskal-Wallis test. \*,  $P < 0.05$ ; \*\*,  $P < 0.01$ ; \*\*\*,  $P = 0.000$ . Group 1: healthy control subjects with a normal WC and non-MS risk factors. Group 2: subjects with a normal WC and metabolic disorders. Group 3: subjects with a normal WC and MS. Group 4: subjects with a larger WC and MS. SAT, subcutaneous adipose tissue; EMCL, extramyocellular lipid; SMR, SAT/muscle ratio; EMR, EMCL/muscle ratio; WC, waist circumference; MS, metabolic syndrome.



**Figure 4** The body composition results for the abdomen between the groups categorized by the WC and presence of MS. Post-hoc multiple comparisons were made with Bonferroni corrections using the Kruskal-Wallis test. \*,  $P < 0.05$ ; \*\*,  $P < 0.01$ ; \*\*\*,  $P = 0.000$ . Group 1: healthy control subjects with a normal WC and non-MS risk factors. Group 2: subjects with a normal WC and metabolic disorders. Group 3: subjects with a normal WC and MS. Group 4: subjects with a larger WC and MS. SAT, subcutaneous adipose tissue; VAT, visceral adipose tissue; EMCL, extramyocellular lipid; SVR, SAT/VAT ratio; SMR, SAT/muscle ratio; VMR, VAT/muscle ratio; EMR, EMCL/muscle ratio; WC, waist circumference; MS, metabolic syndrome.

In terms of performance, the AUCs of the body composition model to diagnose MS in the thigh ranged from 0.681 to 0.768; the SAT and EMCL models performed better (0.768, 0.760) than others with sensitivity rates of 92.73% and 80%, and specificity rates of 57.63% and 69.49%, respectively. There was no difference in the performance of the body composition models in the thigh

( $P > 0.05$ ). The AUCs of the models ranged from 0.702 (SAT: sensitivity: 79.63%, specificity: 70.91%) to 0.788 (VAT: sensitivity: 64.81%, specificity: 80.00%) in the abdomen. The ability of the adipose and muscle parameters to diagnose MS in the abdomen were similar ( $P > 0.05$ ). The ability of the body composition models to diagnose MS after the adjustment of the clinical parameters are displayed

**Table 3** Receiver operating characteristic curve analyses of body compositions in the thigh and abdomen for identifying the presence of metabolic disorders

Model and descriptors	AUC (95% CI)	Youden index	P	Sensitivity	Specificity	P
Thigh (cm <sup>2</sup> )						>0.05
Total area	0.742 (0.651–0.819)	0.5267	0.0001*	66.30%	86.36%	
SAT	0.668 (0.574–0.754)	0.3666	0.0126*	68.48%	68.18%	
EMCL	0.790 (0.597–0.873)	0.4140	0.0041*	64.13%	77.27%	
SMR	0.666 (0.664–0.845)	0.3478	0.0158*	84.78%	53.20%	
Mean	0.791 (0.667–0.884)	0.6432	0.0014*	86.54%	77.78%	
Median	0.675 (0.650–0.872)	0.5278	0.003*	75.00%	77.78%	
SD	0.637 (0.504–0.757)	0.3667	0.2106	66.67%	80.00%	
Abdomen (cm <sup>2</sup> )						>0.05
VAT	0.732 (0.639–0.812)	0.4416	0.0001*	74.16%	70.00%	
SAT	0.741 (0.648–0.820)	0.4803	0.0001*	73.03%	75.00%	
SMR	0.746 (0.654–0.825)	0.5000	0.0001*	75.28%	75.00%	
VMR	0.752 (0.660–0.829)	0.4303	0.0001*	73.03%	70.00%	
Mean	0.703 (0.570–0.815)	0.4755	0.0455*	72.55%	75.00%	
Median	0.733 (0.602–0.840)	0.4559	0.0291*	70.59%	75.00%	
SD	0.717 (0.583–0.849)	0.2157	0.0255*	70.57%	77.25%	

\*, there was a significant difference between groups,  $P < 0.05$ . Group 1: healthy control subjects with a normal WC and non-MS risk factors. Group 2: subjects with a normal WC and metabolic disorders. Group 3: subjects with a normal WC and MS. Group 4: subjects with a larger WC and MS. AUC, area under the curve; CI, confidence interval; SAT, subcutaneous adipose tissue; EMCL, extramyocellular lipid; SMR, SAT/muscle ratio; SD, standard deviation; VAT, visceral adipose tissue; VMR, VAT/muscle ratio; WC, waist circumference; MS, metabolic syndrome.

in Tables 3,4 and Figure 5.

## Discussion

Musculoskeletal system pathological changes (e.g., ectopic fat accumulation, amyotrophy) are associated with the metabolic risk factors (24). This study evaluated body compositions in the thigh and abdomen of CT images. Compared with the control group, more adipose tissue (SAT, VAT, and EMCL) was distributed in the patients with metabolic disorders, who also had a higher adipose tissue and muscle ratio. The accumulation of adipose tissue in the abdomen (SAT and VAT) is often reflected by a larger WC. The results of this study suggest that patients with more adipose tissue but a normal WC have higher metabolic risks. Thus, in addition to obesity, body compositions should also be considered in metabolic condition assessments. Body compositions play an important role in the pathophysiology

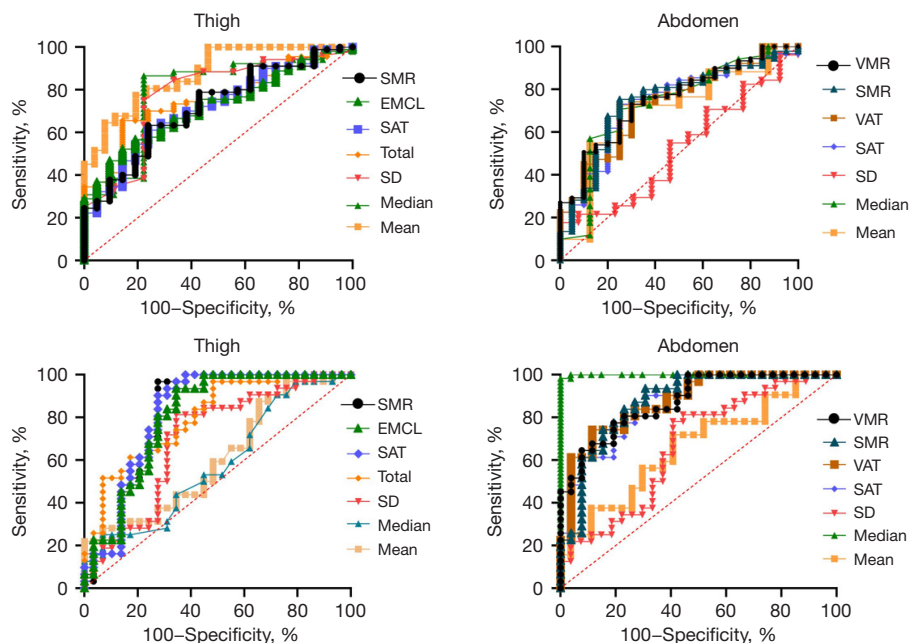
of MS (e.g., oxidation stress, inflammatory cytokines, and adipokines). In the determination of metabolic disorders, the performance of the body composition model was similar in the thigh and the abdomen.

The findings of this study are consistent with those of previous studies, which have shown that MS subjects have more fat accumulation and muscle loss (1,6,11,25–28). In this study, the data suggested that in the abdomen, the SMR and VMR showed sensitivity in detecting metabolic disorders and MS. Conversely, in the thigh, EMCL and mean attenuation were able to detect metabolic disorders with higher sensitivity, while SAT and EMCL were able to detect to MS with higher sensitivity. EMCL accompanied by lower muscle attenuation reflected the degree of fat infiltration and lower muscle quality in the thigh, and had higher AUCs in MS and metabolic disorders. There were no differences between the body compositions of the thigh and abdomen in the diagnosis of metabolic disorders.

**Table 4** Receiver operating characteristic curve analyses of body compositions in the thigh and abdomen for identifying the presence of MS

Model and descriptors	AUC (95% CI)	Cut-off value	P	Sensitivity	Specificity	P
Thigh						>0.05
Total area	0.758 (0.673–0.837)	0.3908	0.001*	76.36%	62.71%	
SAT	0.768 (0.680–0.842)	0.5035	0.001*	92.73%	57.63%	
EMCL	0.760 (0.671–0.835)	0.4949	0.001*	80.00%	69.49%	
SMR	0.754 (0.665–0.830)	0.4598	0.001*	78.18%	67.80%	
Mean	0.709 (0.575–0.831)	0.2198	0.138	87.50%	34.48%	
Median	0.681 (0.534–0.862)	0.1821	0.375	90.62%	27.69%	
SD	0.696 (0.665–0.907)	0.4680	0.005*	81.25%	65.52%	
Abdomen						>0.05
VAT	0.775 (0.686–0.850)	0.4340	0.0001*	87.04%	56.36%	
SAT	0.704 (0.617–0.874)	0.4869	0.0001*	77.78%	70.91%	
SMR	0.702 (0.615–0.872)	0.5050	0.0001*	79.63%	70.91%	
VMR	0.788 (0.686–0.850)	0.4481	0.0001*	64.81%	80.00%	
Mean	0.763 (0.628–0.881)	0.3113	0.0219*	71.87%	59.26%	
Median	0.756 (0.621–0.875)	0.3223	0.0296*	71.87%	59.26%	
SD	0.766 (0.631–0.883)	0.3783	0.0232*	78.12%	59.35%	

\*, there was a significant difference between groups,  $P < 0.05$ . Group 1: healthy control subjects with a normal WC and non-MS risk factors. Group 2: subjects with a normal WC and metabolic disorders. Group 3: subjects with a normal WC and MS. Group 4: subjects with a larger WC and MS. MS, metabolic syndrome; AUC, area under the curve; CI, confidence interval; SAT, subcutaneous adipose tissue; EMCL, extramyocellular lipid; SMR, SAT/muscle ratio; SD, standard deviation; VAT, visceral adipose tissue; VMR, VAT/muscle ratio; WC, waist circumference.



**Figure 5** Receiver operating characteristic curves of body compositions in the thigh (left) and abdomen (right) for the presence of metabolic disorders (upper row) and MS (lower row). SMR, SAT/muscle ratio; EMCL, extramyocellular lipid; SAT, subcutaneous adipose tissue; SD, standard deviation; VMR, VAT/muscle ratio; SMR, SAT/muscle ratio; VAT, visceral adipose tissue; MS, metabolic syndrome.



BMI reflects general obesity, while body compositions offer more metabolism information for subjects with a normal BMI, providing information about ectopic fat accumulation (SAT, VAT, and EMCL), and muscle atrophy. CT examinations have been used as a reliable and non-invasive tool in the diagnosis of musculoskeletal diseases, and allow for the detailed body composition assessment of adipose tissue and muscle (6). EMCL measurements based on CT can be used to assess increased cardiometabolic risks in chronic obstructive pulmonary disease patients (29). Measurements of myocardial, pericardial and perivascular adipose tissue by CT images can assist in the diagnosis of coronary artery diseases (30-32).

The growing prevalence of MS in the population has attracted attention worldwide. MS is associated with several risk factors, such as smoking, sex hormone deficiency, low-grade inflammation, and increased oxidative stress (2). A number of studies have emphasized the importance of VAT, pericardial and perirenal adipose tissue in metabolic disorders; however, few studies have focused on adipose tissue changes in muscle, especially EMCL, in metabolic disorders. In the musculoskeletal system, proinflammatory cytokines increase the rate of lipolysis of skeletal muscle in chronic metabolism conditions (6). Adipose and muscle dysfunction can aid in the diagnosis and prognosis of metabolic disorders in clinical practice (33). An inverse association has been reported between thigh muscle mass and MS (34), and the ratio between adipose tissue and muscle changes could be an indicator of the MS (35). Visceral fat has been shown to be correlated with early atherosclerotic changes in diabetes and MS (36).

This study had several limitations. The sample size of the study was small, which lowers the generalizability of the findings. Several factors, such as lifestyle and diet, may affect body composition metabolism, but these factors were not considered in this study. The subjects in the control group were from the same hospital, thus this study might be affected by selection bias. Further investigations with a large population and more comprehensive assessments are needed in the future.

## Conclusions

The body compositions parameters of EMCL, VMR, VAT, and muscle quality could offer information and assist in detecting patients with an increased risk of MS. The ability of the body composition models to detect metabolic disorders was similar in the thigh and the abdomen. The

results need to be confirmed in a larger population.

## Acknowledgments

*Funding:* This study was supported by the National Natural Science Foundation of China (NSFC) (Nos. 81930045 and 31630025).

## Footnote

*Reporting Checklist:* The authors have completed the STROBE reporting checklist. Available at <https://qims.amegroups.com/article/view/10.21037/qims-23-1724/rc>

*Conflicts of Interest:* All authors have completed the ICMJE uniform disclosure form (available at <https://qims.amegroups.com/article/view/10.21037/qims-23-1724/coif>). The authors have no conflicts of interest to declare.

*Ethical Statement:* The authors are accountable for all aspects of the work, including ensuring that any questions related to the accuracy or integrity of any part of the work have been appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Institutional Review Board of the Tongji Hospital (TJ-IRB20210602), and the requirement of informed consent for this retrospective analysis was waived.

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**Cite this article as:** Hou B, Li Y, Liu C, Zhang Y, Wen D, Li X. Assessment of body compositions in the prediction of metabolic syndrome in adults. *Quant Imaging Med Surg* 2024;14(8):5891-5901. doi: 10.21037/qims-23-1724