

# Correlation Between the Distribution of Abdominal, Pericardial and Subcutaneous Fat and Muscle and Age and Gender in a Middle-Aged and Elderly Population

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**Objective:** The present study aimed to explore the relationships between the distribution of abdominal fat and muscle and age and gender in a middle-aged and elderly population.

**Methods:** The levels of abdominal (visceral and subcutaneous) fat, pericardial fat, and psoas major muscle were measured in subjects who had physical examinations at the Health and Medical Department of Peking Union Medical College Hospital from July 2019 to June 2020. The relationship between fat in different areas (ie, different types of fat) and the relationship between different types of fat and the psoas major muscle were investigated in the context of different genders and ages.

**Results:** The distribution of fat and muscle differed between males and females of the middle-aged and elderly study sample. Volumes of pericardial fat, total abdominal fat, and visceral fat were significantly lower in females than in males, and the area of the psoas major muscle was also significantly lower in females than in males. Levels of subcutaneous fat and total abdominal fat showed no significant correlation with age. The level of muscle showed a significant negative correlation with age.

**Conclusion:** 1) Within the middle-aged and elderly sample, male subjects had higher levels than females of all types of fat except for abdominal subcutaneous fat, and had higher levels of psoas muscle than females. 2) Pericardial fat increased with age, whereas levels of abdominal fat did not change significantly with age. 3) The area of psoas major muscle appears to be positively correlated with volumes of all types of fat: subjects with more fat tended to have higher levels of psoas major muscle.

**Keywords:** middle-aged and elderly, abdominal fat, pericardial fat, psoas major muscle, age, gender

## Introduction

In recent years, obesity has become an increasingly prominent social and medical problem both in China and globally. Obesity is accurately described as the presence of unhealthily excessive fat, increasing the risk of disease and death.<sup>1</sup> Simple commonly used assessment methods include body mass index (BMI) and waist circumference measurement; more accurate methods for assessing fat require the use of dual-energy X-ray absorptiometry (DXA), computerised tomography (CT), or magnetic resonance imaging (MRI). The accuracy of BMI and waist

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circumference in assessing fat volumes is poor,<sup>2</sup> and the accuracy is further reduced as patient age increases. In addition, the value of body fat has better predictive validity than BMI for the risk of metabolic syndrome<sup>3</sup> and cardiovascular diseases.<sup>4</sup> Muscle loss increases the risk of fractures and falls<sup>5</sup> and affects quality of life and the ability to perform day-to-day tasks,<sup>6</sup> and the need for long-term care of those elderly people who have lost the ability to live independently is a heavy burden on society.<sup>7–9</sup> Muscle loss is also correlated with heart disease,<sup>10</sup> respiratory disease,<sup>11</sup> and even mortality.<sup>12</sup> Studies concerning the distribution of fat and muscle in the population are essential for the prevention and treatment of chronic diseases. However, there is a lack of studies focusing specifically on middle-aged and elderly patients, especially studies specific to abdominal (subcutaneous and visceral) fat, pericardial fat, and muscle. Therefore, the present study investigated the correlation between abdominal fat, pericardial fat, and muscle in middle-aged and elderly people of different genders and ages. With the widespread availability of CT scanners, as well as their advantages as simple, reliable, and non-invasive means of assessing the distribution of visceral fat and muscle, the CT examination is considered the current gold standard for measuring levels of fat and muscle. The properties of tissues can be judged by the CT values in combination with computer software to accurately calculate the levels of fat and muscle in the body.

## Subjects and Methods

### Study Subjects

The data of patient subjects undergoing physical examination at the Health and Medical Department of Peking Union Medical College Hospital from July 2019 to June 2020 were analyzed. Levels of psoas major muscle in the subjects were measured from September 2020.

The COVID-19 infection was excluded from all subjects undergoing physical examinations after 2020. Subjects with acute infections, new onset of severe trauma, surgical history, newly discovered tumors, and endocrine diseases that might cause significant changes in weight, such as hyperthyroidism, were excluded.

### Methods

The present study was a retrospective cross-sectional study. The physical examination subjects were all covered by medical reimbursements. The general information of

each examinee (including gender, age, height, body weight, waist circumference, and blood pressure) was collected and the BMI calculated. Waist circumference was measured from the plane of the anterior superior iliac crest at the end of expiration to the midpoint of the lower costal margin. BMI was calculated as body mass (kg)/body height (m). Thoracic, abdominal, and pelvic CT was conducted in all subjects, and measurements of abdominal fat and pericardial fat were taken for all subjects.

The CT scanner was the Siemens Definition Flash with CARE Dose 4D, with scanning condition 120 kV, scanning thickness 0.5 mm, and B30f reconstruction. In [Figure 1](#), “pericardial fat” refers to the volume of fat (in cm<sup>3</sup>) within the pericardium on the CT image, with the inferior border of the heart as the lower edge and the aortic bifurcation as the upper edge. Measurement of abdominal fat (in cm<sup>3</sup>) was taken with the diaphragm as the upper edge of the abdominal border, and the upper edge of the iliac crest as the lower edge: all fat in this region was recorded as abdominal fat. The volume of abdominal visceral fat was measured (in cm<sup>3</sup>) as the volume of fat inside the peritoneum, and the volume of abdominal subcutaneous fat was measured (in cm<sup>3</sup>) as the volume of fat outside the peritoneum. The volume of pelvic visceral fat (in cm<sup>3</sup>) was the volume of all intra-peritoneal fat from the upper edge of the iliac crest to the lower edge of the pelvic floor. The psoas major muscle was measured at the level of the lumbar 3 intervertebral disc, and the area of the psoas major muscle was taken as the sum of the bilateral psoas major muscle area (in cm<sup>2</sup>).

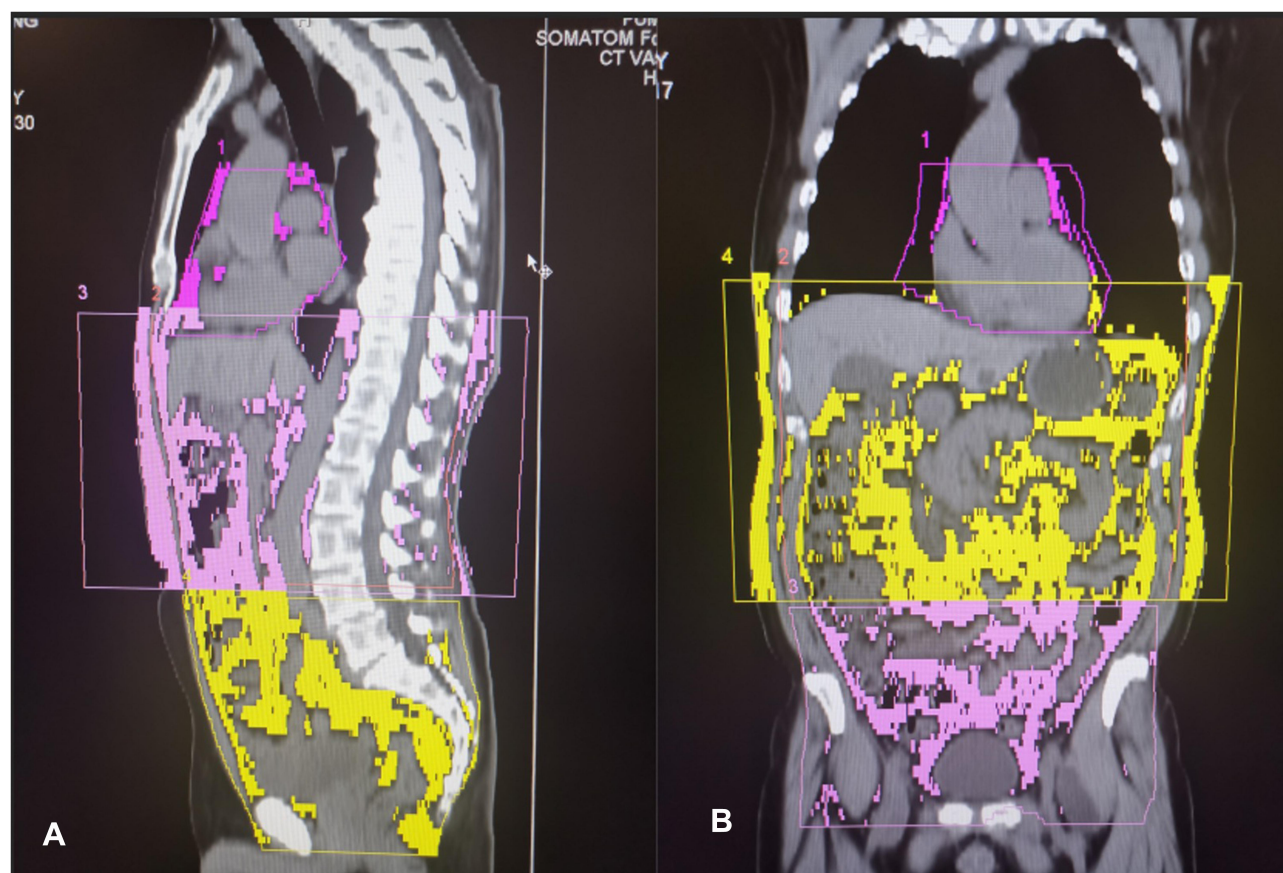
### Statistic Processing

All research data were recorded using EXCEL 2010, and data was analyzed using SPSS 24.0. Age, body weight, height, waist circumference, BMI, volume of abdominal visceral fat, volume of abdominal subcutaneous fat, total abdominal fat, percentage of abdominal visceral fat, volume of pericardial fat, and area of psoas muscle were all expressed by  $x \pm s$ . A two-tailed *t*-test was used for numerical comparison between groups.  $P < 0.05$  was considered statistically significant.

## Results

### Distribution of the General Characteristics of the Patients Undergoing Physical Examinations ([Tables 1 and 2](#))

In those aged 50–100 years in the population who underwent physical examination, a total of 471 patients



**Figure 1** Schematic diagram of the measurement of abdominal fat. **(A)** Sagittal CT of the chest and abdomen. The marked area indicates abdominal fat (including subcutaneous fat and visceral fat), the yellow area indicates pelvic visceral fat, and the area around the heart is pericardial fat. **(B)** Coronal CT of the chest and abdomen. The marked area indicates abdominal fat (including subcutaneous fat and visceral fat), the yellow area indicates pelvic visceral fat, and the area around the heart is pericardial fat.

underwent CT examinations of the chest, abdomen, and pelvis, including 409 males and 62 females. Testing indicated that the distribution of the data concerning fat and muscle in each group conformed to normal distribution.

### Levels of Fat and Muscle in Middle-Aged and Elderly People of Different Genders (Table 3)

In the population aged over 50 years, males and females had different distributions of fat and muscle. Females had significantly less pericardial fat and significantly less abdominal visceral fat than males, thus females had significantly less visceral fat than males. The level of total abdominal fat in females was significantly less than that in males. There was no significant difference between females and males in terms of volumes of abdominal subcutaneous fat.

### Correlation of Age with Levels of Fat and Muscle (Table 4)

Levels of subcutaneous fat and total fat had no significant correlation with age. The level of muscle showed a significant negative correlation with age.

### Correlation of Pericardial Fat with Abdominal Fat (Table 5)

For subjects aged over 50 years, there existed significant correlation between volume of pericardial fat and volume of other types of fat, BMI, and waist circumference; of these, the correlation between levels of pericardial fat and visceral fat and waist circumference was most obvious.

### Correlation Between Area of Psoas Major Muscle and Volume of Abdominal Fat (Table 4)

For those aged over 50 years, the area of the psoas major muscle was correlated with the volume of abdominal fat.

**Table 1** The General Characteristics of the Patients

	Number of Cases	Value (Mean to $\pm$ Standard Deviation)	Range
Age year	471	69 $\pm$ 11	50–100
Pericardial fat cm <sup>3</sup>	468	94.14 $\pm$ 60.90	4.41–342.17
Pelvic visceral fat cm <sup>3</sup>	469	2665.87 $\pm$ 1824.52	168.02–9505.26
Total abdominal fat cm <sup>3</sup>	471	5766.62 $\pm$ 2477.14	497.71–19,829.16
Abdominal visceral fat cm <sup>3</sup>	471	2859.85 $\pm$ 1260.13	225.74–9401.83
Abdominal subcutaneous fat cm <sup>3</sup>	471	2906.77 $\pm$ 1621.08	228.99–10,731.86
Percentage of abdominal visceral fat %	471	50.0% $\pm$ 12.2%	12.2–78.2%
Abdominal and pelvic visceral fat cm <sup>3</sup>	469	5525.29 $\pm$ 2652.89	572.45–16,821.96
Psoas major muscle cm <sup>2</sup>	278	8.92 $\pm$ 2.28	3.43–15.66
Low-density lipoprotein cholesterol mmol/L	470	2.70 $\pm$ 0.89	0.81–6.30
High-density lipoprotein cholesterol mmol/L	470	1.29 $\pm$ 0.32	0.54–3.26
Triglyceride mmol/L	470	1.51 $\pm$ 1.03	0.43–13.50
Total cholesterol mmol/L	470	4.19 $\pm$ 0.96	2.20–7.65
BMI Kg/m <sup>2</sup>	458	25.5 $\pm$ 2.98	15.1–43.5
Waist circumference cm	468	91.5 $\pm$ 8.61	60.0–145.0

**Table 2** Clinical Data of the Patients

Diabetes Mellitus	Patients with Impaired Fasting Glucose	Normal People
179 (38%)	38 (8.1%)	254 (53.9%)
Hypertension	No hypertension	
284 (60.3%)	187 (39.7%)	
Gout	Elevated uric acid level	Normal uric acid level
25 (5.3%)	168 (35.9%)	277 (58.8%)
Coronary heart disease	Coronary atherosclerosis	No coronary atherosclerosis
	97 (20.6%)	311 (66.0%)
After treatment of old myocardial infarction or recanalization: 27 (5.7%).		
A history of coronary heart disease without the need for recanalization: 36 (7.6)		

## Discussion

It is generally believed that obesity is a risk factor for all-cause mortality regardless of the presence of common metabolic abnormalities.<sup>13</sup> Studies in the last century confirm that central obesity is associated with the risk of diabetes mellitus,<sup>14,15</sup> cardiovascular disease and events,<sup>16,17</sup> and hypertension.<sup>18</sup> Since the beginning of this century, it has been discovered that obesity is related to overall risk of sleep apnea,<sup>19</sup> cancer,<sup>20</sup> and mortality.<sup>21</sup> Mortality in males and females with waist circumference in the highest 20% of the population is almost twice that in those with waist circumference in the lowest 20%.

According to the fat volume measurement in the present study, total abdominal fat was lower in females than in males; this was especially the case for abdominal visceral fat.

Analysis of the US 1999–2006 National Health and Nutrition Examination Survey (NHANES) data shows that for a population with an average age of 46, BMI and body fat percentage were lower in males than in females, whereas waist circumference was higher in males than in females. That study included mainly white, Hispanic, and non-Hispanic black individuals.<sup>22</sup> In the present study, all subjects were of East Asian “yellow races” and were relatively older, with an average age of 69; the population was characterized by relatively affluent living and medical conditions. Under these conditions, it was found that BMI and waist circumference were significantly higher in males than in females. Concerning fat distribution, with the exception of abdominal subcutaneous fat, the volume of which was similar in males and females, volumes of all other fat types (pericardial, abdominal visceral, and pelvic fat) were significantly higher in males; the area of muscle was also significantly higher in males than in females. Although the current mainstream view is that waist circumference should be evaluated separately in males and females, some papers claim that the same standard of waist circumference should be used for both genders.<sup>22</sup>

Adipocytes around the heart originate from the mesoderm and have the same embryonic origin as mesenteric and omental adipocytes.<sup>23</sup> Under normal circumstances,

**Table 3** Fat and Muscle Levels in Middle-Aged and Elderly People of Different Genders

Item	Gender	Number of Cases	Value (Mean to $\pm$ Standard Deviation)	Homogeneity of Variance Test F (Significance)	T	P
Age year	M F	409 62	69 $\pm$ 11 68 $\pm$ 11	0.077 (0.782)	0.900	0.369
Pericardial fat cm <sup>3</sup>	M F	406 62	97.65 $\pm$ 62.38 71.15 $\pm$ 44.47	6.978 (0.009)	4.115	<0.001
Pelvic visceral fat cm <sup>3</sup>	M F	407 62	2776.00 $\pm$ 1877.27 1942.96 $\pm$ 1213.14	29.869 (<0.001)	4.628	<0.001
Total abdominal fat cm <sup>3</sup>	M F	409 62	5886.82 $\pm$ 2508.43 4973.70 $\pm$ 2111.24	1.129 (0.288)	2.723	0.007
Abdominal visceral fat cm <sup>3</sup>	M F	409 62	3023.15 $\pm$ 1220.27 1782.62 $\pm$ 957.58	4.015 (0.046)	9.138	<0.001
Abdominal subcutaneous fat cm <sup>3</sup>	M F	409 62	2863.67 $\pm$ 1650.82 3191.0818 $\pm$ 1387.65	1.324 (0.250)	-1.484	0.139
Percentage of abdominal visceral fat %	M F	409 62	52.3% $\pm$ 10.8% 34.9% $\pm$ 10.3%	0.223 (0.637)	11.890	<0.001
Abdominal and pelvic visceral fat cm <sup>3</sup>	M F	407 62	5799.45 $\pm$ 2636.36 3725.58 $\pm$ 1985.33	7.159 (0.008)	7.303	<0.001
Psoas major muscle cm <sup>2</sup>	M F	241 37	9.36 $\pm$ 2.06 6.01 $\pm$ 1.32	7.341 (0.007)	13.141	<0.001
Low-density lipoprotein cholesterol mmol/L	M F	409 61	2.69 $\pm$ 0.90 2.78 $\pm$ 0.84	0.645 (0.422)	-0.782	0.435
High-density lipoprotein cholesterol mmol/L	M F	409 61	1.24 $\pm$ 0.28 1.58 $\pm$ 0.41	10.863 (0.001)	-6.119	<0.001
Triglyceride mmol/L	M F	409 61	1.53 $\pm$ 1.07 1.40 $\pm$ 0.76	0.853 (0.356)	0.928	0.354
Total cholesterol mmol/L	M F	409 61	4.14 $\pm$ 0.94 4.52 $\pm$ 0.98	0.137 (0.711)	-2.957	0.003
BMI Kg/m <sup>2</sup>	M F	396 62	25.78 $\pm$ 2.88 24.03 $\pm$ 3.15	0.355 (0.551)	4.390	<0.001
Waist circumference cm	M F	406 62	92.48 $\pm$ 8.13 85.36 $\pm$ 9.16	3.016 (0.083)	6.311	<0.001

pericardial fat accounts for approximately 20% of heart weight.<sup>24</sup> Pericardial fat is concentrated mainly in the atrioventricular and ventricular grooves, so the coronary arteries and their main branches are usually buried in the pericardial fat. Data from the Framingham Heart Study published in 2008 shows that pericardial fat and obesity (measured by weight and waist circumference) were correlated with various indicators of risk factors in cardiovascular disease (hypertension, hypertriglyceridemia, low high-density lipoprotein cholesterolemia, impaired fasting

blood glucose, and diabetes mellitus), and had a significant correlation with metabolic syndrome. The correlation with the metabolic risk factors still existed after adjustment for body weight and waist circumference, but there was no significant difference after adjustment for abdominal visceral fat level.<sup>25–27</sup> Further studies have found that pericardial fat is an independent risk factor for coronary atherosclerosis, and that with every 10 cm<sup>3</sup> increase in the volume of coronary fat, the probability of progression of coronary calcification score increases by 12%<sup>28</sup>. In the



**Table 4** The Correlation Between Age and Fat of Different Parts and Psoas Major Muscle

	Pericardial Fat	Pelvic Visceral Fat	Total Abdominal Fat	Abdominal Visceral Fat	Abdominal Subcutaneous Fat	Percentage of Abdominal Visceral Fat	Abdominal and Pelvic Visceral Fat	Psoas Major Muscle	BMI	Waist Circumference cm
Person correlation coefficient	0.164	0.074	0.059	0.088	0.022	0.082	0.092	-0.272	-0.031	0.069
Significance	<0.001	0.108	0.202	0.056	0.641	0.075	0.046	<0.001	0.514	0.135
Person correlation coefficient	0.213	0.167	0.270	0.357	0.147	0.194	0.299	0.448	0.404	
Significance	<0.001	0.005	<0.001	<0.001	0.014	0.001	<0.001	<0.001	<0.001	
The number of bias after removing the age	0.251	0.211	0.297	0.401	0.156	0.227	0.351	0.471	0.445	
Significance	<0.001	0.001	<0.001	<0.001	0.010	<0.001	<0.001	<0.001	<0.001	

**Table 5** The Correlation Between the Pericardial Fat and Abdominal Fat and Psoas Major Muscle

	Pelvic Visceral Fat	Total Abdominal Fat	Abdominal Visceral Fat	Abdominal Subcutaneous Fat	Abdominal Subcutaneous Fat	Percentage of Abdominal Visceral Fat	Abdominal and Pelvic Visceral Fat	Psoas Major Muscle	BMI	Waist Circumference cm
Person correlation coefficient	0.197	0.343	0.435	0.185	0.253	0.253	0.343	0.213	0.320	0.410
Significance	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
The number of bias after removing the age	0.188	0.302	0.482	0.107	0.346	0.380	0.380	0.251	0.379	0.441
Significance	0.002	<0.001	<0.001	0.082	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

population with a coronary calcification score of 0, pericardial fat is also an important predictor for coronary non-calcified plaque.<sup>29</sup>

In the present study, males had significantly more pericardial fat than females. In terms of the relationships between pericardial fat and other fat types, the correlation between volumes of pericardial fat and abdominal visceral fat is the most obvious; the correlation between pericardial fat and abdominal subcutaneous fat is less clear. This may be because pericardial fat and abdominal visceral fat share a common origin. Unlike other fat types, which display no significant correlation with age, pericardial fat is in a statistically weak positive correlation with age. This might suggest a slow increase in volume of pericardial fat with age; further longitudinal studies are required to assess this.

Sarcopenia is an important manifestation of aging. The common signs of sarcopenia include decreased muscle strength, decreased muscle mass, and decreased physical function.<sup>30</sup> Muscle volume can be measured by bioelectrical impedance analysis, DXA, CT, or MRI; muscle volume results as detected by CT and MRI are currently considered the benchmark. The horizontal area of the psoas major muscle can be easily measured by CT, and the psoas major index has been suggested as a possible value for assessing muscle volume throughout the body.<sup>31</sup> To date, several studies have found a correlation between the level of psoas major muscle and arteriosclerosis and coronary heart disease in non-elderly individuals.<sup>32</sup> In the middle-aged and elderly subjects enrolled in the present study, the area of psoas major muscle decreased with age, but was positively correlated with volumes of abdominal and pericardial fat. It is therefore suggested that the level of psoas major muscle might be significantly correlated with nutritional status in middle-aged and elderly individuals. The correlation was more obvious after adjusting for age. In recent years, sarcopenic obesity in the elderly has been a focal issue in geriatrics. However, the results of the present study suggest that where both sarcopenia and obesity exist, there would be a risk of further muscle loss if fat volume were reduced. Clinically, therefore, further research into the control of fat levels in the elderly is necessary. However, our limitation is that the majority of participants were males (87%) in the whole study, which may suggest a sex bias. And HDL and total cholesterol were higher among females than in males, but we did not assess the possible effects of these changes in lipid profiles on the correlation of fat depots.

## Conclusion

Among the middle-aged and elderly study population, volumes of fat of all types, except for abdominal subcutaneous fat, were higher in males than in females, and males also had higher levels of the psoas major muscle than females. Pericardial fat volume increased with age while abdominal fat volume did not change significantly with age. The area of the psoas major muscle was positively correlated with the volume of each type of fat, ie, individuals with more fat tended to have higher levels of psoas major muscle.

## Ethics Approval and Consent to Participate

This study was conducted in accordance with the declaration of Helsinki. This study was conducted with approval from the Ethics Committee of Peking Union Medical College Hospital. A written informed consent was obtained from all participants.

## Consent for Publication

Consent for publication was obtained from every individual whose data are included in this manuscript.

## Disclosure

All authors have contributed significantly to the manuscript and declare that the work is original. None of the authors have any financial disclosures or conflicts of interest.

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