Age-related fatty infiltration of lumbar paraspinal muscles: a normative reference database study in 516 Chinese females

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Background: Fatty infiltration, as a result of aging, is an essential biomarker of muscle degeneration. This research aimed to investigate the age-dependent change of fatty degeneration in the paraspinal muscles of healthy Chinese women. This study also explores the effect of body size on fatty infiltration of paraspinal muscles.

Methods: Cross-sectional area of paraspinal muscles (CSA_{muscle}) and intermuscular adipose tissue (CSA_{IMAT}) were measured at the L3 mid-vertebral level of 516 healthy females, who underwent abdomen quantitative computed tomography (QCT) scans. Subsequently, IMAT% [CSA_{IMAT} / (CSA_{IMAT} + CSA_{muscle})] were calculated. The relationship between basic information and measurements was evaluated using Spearman correlations. Comparisons of QCT results among different BMI subgroups in different age groups were analyzed with the Kruskal-Wallis H test and LSD, post-hoc correction. Age-related changes were calculated after the adjustment of height and weight.

Results: The mean CSA_{IMAT} of 20–29 years group (n=69) and 70–79 years group (n=25) were 3.00 cm^2 and 11.06 cm^2, respectively. While the mean CSA_{muscle} of 20–29 years group was 38.46 cm^2 and 70–79 years group was 30.86 cm^2. The mean IMAT% difference between 20-29 years group and 70–79 years group was –18.55%. Strong, positive non-linear associations were observed between ageing and CSA_{IMAT}, along with IMAT% (r=0.656, P<0.01; r=0.714, P<0.01). However, CSA_{muscle} was shown to decrease with age in a weak, negative linear fashion (r=–0.265, P<0.01). Positive relationships between BMI and CSA_{IMAT}, CSA_{muscle}, along with IMAT%, were found. Significant differences were observed between obesity and normal BMI subgroup for all variables in three age groups. CSA_{IMAT} showed a larger age-related difference compared to CSA_{muscle}.

Conclusions: Fatty infiltration in paraspinal muscles increased with age and BMI, while muscle loss may be associated with aging. The present study provided standardized reference data for the fatty degeneration of paraspinal muscles across the adult lifespan of Chinese females, which will play a critical role in future studies.

Keywords: Intermuscular adipose tissue; paraspinal muscle; quantitative computed tomography (QCT); healthy female population

Introduction

Atrophy and fatty infiltration of muscle with aging are associated with sarcopenia, obesity, and osteoporosis (1-4). The muscle imaging assessment is of increasing interest in musculoskeletal research, especially in sarcopenia. Sarcopenia is an aging-related condition, defined by a progressive and generalized loss of muscle mass and function (5,6). Two commonly used techniques to assess lean and fat mass are dual X-ray absorptiometry (DXA) and bioelectrical impedance (BIA). However, neither of them provides a spatial distribution of muscle and adipose tissue. Fatty infiltration, as a result of the aging process, has been shown as an essential biomarker of muscle degeneration (7,8). The advantage of using CT (and MRI) over DXA or BIA in related investigations is the ability to assess fatty infiltration. Thus, CT or MRI will be critical techniques to address the pathophysiology of sarcopenia (9,10).

The relationship between trunk muscle, particularly paraspinal muscle deficits, and disc degeneration disease of the lumbar spine, along with kyphosis, had raised considerable attention (11-13). Moreover, lumbar muscle degeneration is a common feature in low back pain. Visibly, this muscle degeneration is characterized by a decreased cross-sectional area (muscle atrophy) and an increase in fat content (fatty infiltration) in the lumbar paraspinal muscles (14). Although changes in muscle size and fat infiltration of the lumbar muscles are frequently reported in low back pain literature, age-related physiological changes of paraspinal muscle were not well studied. The lack of references related to structural changes makes it difficult to draw abnormal identification. Multiple published reports establish the use of CT and MRI in assessing paraspinal muscle degeneration. CT scanning shows this phenomenon by density or size, while MRI detects paraspinal muscle degeneration by muscle properties (15-21). However, most of these studies were retrospectively based on images of patients with chronic low back pain, and little is known about atrophy and fatty infiltration of paraspinal muscle in a healthy population.

Furthermore, paraspinal muscle aging within the Chinese population is not well studied, despite China having the largest population in the world, which is also rapidly aging. To our knowledge, age-related reference data of atrophy and fatty infiltration of paraspinal muscles during adulthood of healthy Chinese females have not been reported. The diagnostic cutoff values for pathologic paraspinal muscle atrophy in the Chinese population may differ from Caucasians due to genetic factors, environmental conditions, body size, and lifestyles. The purpose of this study was to: (I) assess the age-related differences in paraspinal muscle in healthy Chinese females aged 20–80 years; (II) provide reference data of paraspinal muscle and visible deposit of adipose tissue; (III) explore how body size affects fatty infiltration of paraspinal muscle.

Methods

Subjects

Five hundred and sixteen subjects (21 to 79 years old) in this cross-sectional study originated from two cohorts. One cohort comprised of 344 healthy women and was recruited from an ongoing study that has been running since June 2014. This ongoing study examined the degeneration of the spine and knee, described previously (22). The second cohort comprised of one hundred and seventy-two women from the Prospective Urban Rural Epidemiology (PURE) China Action on Spine and Hip status (CASH) study (23,24). All women were living independently in the community, with details of eligibility and recruitment previously published (22,24). In brief, for the degeneration of the spine and knee study, the criteria for inclusion were healthy adults, aged 20–65 years, and a resident of Beijing >5 years; for the PURE CASH study, the inclusion criteria were healthy adults aged over 40 years. This study included study subjects from Beijing Jishuitan Hospital. Participants with previous and current use of hormones were excluded. Additional criteria for exclusion were a severe organic disease, systemic metabolic bone disease, lipodystrophy, and recent history of lumbar vertebrae fracture and surgery. A flowchart detailing stepwise inclusion and exclusion of the subjects is presented in *Figure 1*. We have obtained ethical approval from the ethics committee of the Beijing Jishuitan Hospital (Approval No. 201210-01 and No. 201512-02). The study is conducted following ethical principles according to the Declaration of Helsinki and is consistent with Good Clinical Practice. Radiation safety and protection measures are strictly implemented in the whole study. Informed consent was obtained from all participants in the study.

Anthropometry

Height (nearest 0.1 cm) and bodyweight (nearest 0.01 kg) were measured with a standard height and weight scale. BMI was calculated using formula: Weight/Height^2 (kg/m^2).
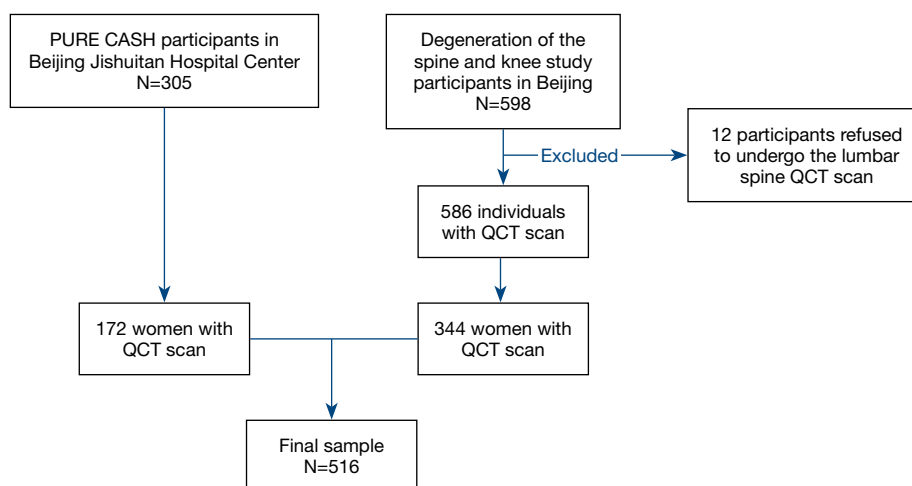
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Figure 1 Flow chart of participant selection for the study.

A BMI <24 kg/m^2 was considered normal; 24–28 kg/m^2 was considered overweight; >28 kg/m^2 was defined obesity based on the Chinese criteria (25).

QCT scans

Spine QCT scans of the cohort were acquired from a Toshiba Aquilion 80-slices CT scanner (Toshiba Medical Systems, Tokyo, Japan) together with a Mindways calibration phantom (Mindways Software Inc., Austin, TX, USA). The lumbar were scanned in the supine position from L1 to L5. Acquired scan parameters included exposure factors of 120 kVp, 187 mAs, 1-mm slice thickness, and 40 cm field of view (DFOV), with standard reconstruction.

Measurements of paraspinal muscles and fat

Images were transferred to a QCT Pro workstation (Mindways Software, Version 4.2.3; Mindways, Austin, TX, USA) by the image transfer utility set up on the CT scanner. We measured the cross-section area (CSA) of paraspinal muscles, including multifidus muscle and erector spinae muscle, and intermuscular adipose tissue (IMAT) at the mid-vertebral level slice of L3. In our study, IMAT was defined as an ectopic fat deposit beneath the fascia and within the muscles following Addison's review (26). Simultaneously, measurements of CSA of paraspinal muscles (CSA$_{muscle}$) and IMAT (CSA$_{IMAT}$) were both semi-automatically completed by the commercial software package: "Tissue Composition Module" Beta 1.0 (Mindways, Austin, TX, USA). The QCT Pro Tissue

Composition Module could define an optional contour around a muscle or group of muscles. A spline was used to constrain the location of the contour, and a "snake" operation fitted the contour precisely to the muscle group (*Figure 2*). The resulting spline boundary can be modified by the user, as needed, by moving the spline control points. In contrast to absolute HU values based on CT images in the literature (14), HU measurements based on QCT imaging are converted into tissue (i.e., Muscle and fat) densities by scanning the subject together with a calibration phantom containing standards representing known densities of bone and soft tissue. In this study, the Tissue Composition Module of QCT automatically selected the water (H$_2$O) basis set equivalent density as segmentation thresholds based on calibration data from CT images. The density thresholds used for fat segmentation were 833 to 995 mg/cm^3 H$_2$O. Segmentation thresholds for muscle were 996 to 1,153 mg/cm^3 H$_2$O. Subsequently, IMAT% (CSA$_{IMAT}$ / CSA$_{IMAT}$ + CSA$_{muscle}$) indicating fatty infiltration of muscle were calculated, based on the measurements of muscle CSA and IMAT CSA. The intra-observer reproducibility of the measurements for fat and paraspinal muscles CSA of L3 was high, with intraclass correlation coefficients of 0.996 and 0.993, respectively. The inter-class correlation coefficients of measurements for fat and muscle CSA were 0.995 and 0.981.

Statistical analysis

Data were expressed as mean ± SD. Kruskal-Wallis H test was used to compare the differences in anthropometric

Subjects of different BMIs
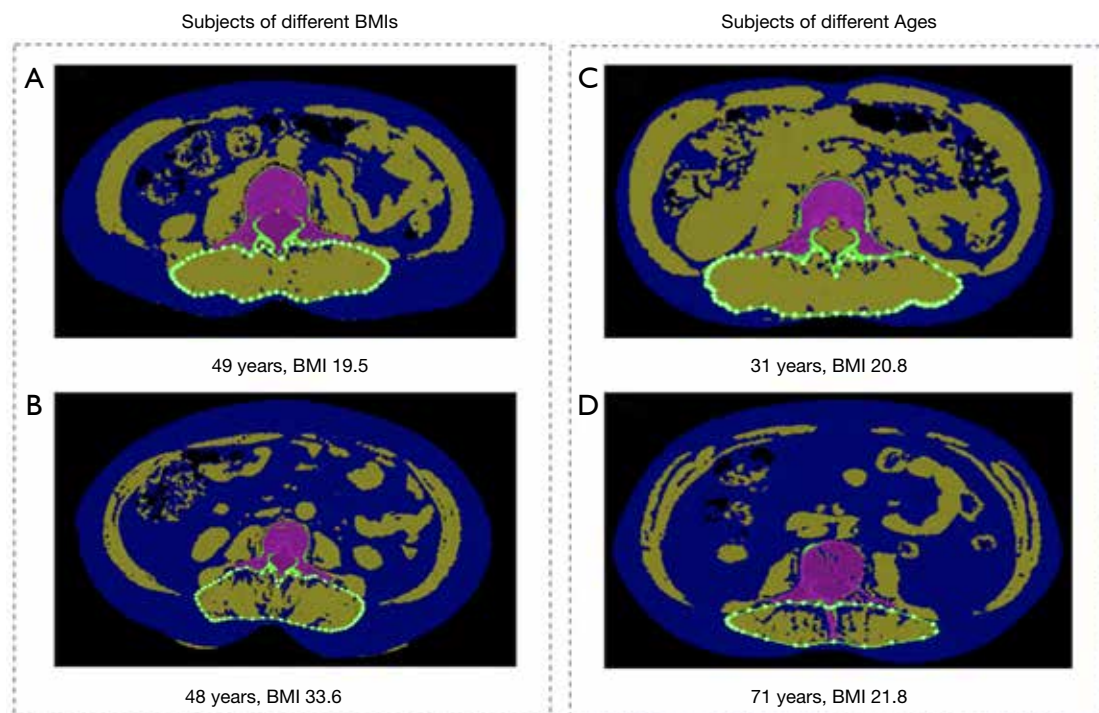
Subjects of different Ages

Figure 2 Measurements of paraspinal muscles and fat using the QCT Pro Tissue Composition Module in subjects with differing BMIs and ages. A spline was used to constrain the location of the contour, and a "snake" operation fitted the contour precisely to the paraspinal muscle group (multifidus muscle and erector spinae muscle) at the mid-vertebral level of L3. Intermuscular adipose tissue in the muscle group shown in blue, and muscle tissue are shown in yellow. BMI, body mass index.

characteristics and measurement results among age groups by decade. Kruskal-Wallis H test and LSD post-hoc correction was used to compare the results among BMI subgroups in young (20–39 years), middle-aged (40–59 years), and elderly (60–79 years) groups, respectively. The relationships between age, height, weight, BMI, and measurements of paraspinal muscles and IMAT were evaluated using Spearman correlations, depending on the distribution of the variables. Correlation coefficient r between 1.0 and 0.5 was considered strong; 0.5–0.3, moderate; and 0.3–0.1, weak. We used the Lowess curve fitting to determine if there was a linear or nonlinear correlation between age and paraspinal muscles and IMAT measurements. Analysis of covariance was used to calculate the interaction of age and BMI for parameters. Changes in measurement results with age, by decade, were calculated using height and weight as covariate variables. Statistical analyses were performed by using commercial software (SPSS, Version 25 for Mac; IBM, Armonk, New York, USA). $P<0.05$ was considered statistically significant.

Results

Anthropometric characteristics and measurements of paraspinal muscles and IMAT

The mean age of 516 healthy Chinese females was 45.12±13.41 years (range, 21–79 years). The anthropometric parameters and measurements of paraspinal muscles and fat among age groups by decade are provided in *Table 1*. Interaction between age and BMI was significant for CSA_{IMAT}. Significant differences in height, weight, BMI, CSA_{muscle}, and IMAT% were found among age groups by decade.

The effect of body size on CSA_{IMAT}, CSA_{muscle} and IMAT% in different age groups

Table 2 and *Figure 3* show measurement results among BMI subgroups in young (20–39 years), middle-aged (40–59 years), and elderly (60–79 years) groups. All age groups displayed significant differences between obesity and

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Table 1 Anthropometric characteristics and measurement results of paraspinal muscles and IMAT in 516 healthy Chinese women according to age by decade

Variable	20–29 years (n=69)	30–39 years (n=127)	40–49 years (n=140)	50–59 years (n=88)	60–69 years (n=67)	70–79 years (n=25)	P	Age*BMI interaction (P)
Age (years)	26.84±2.03	34.39±2.88	44.21±2.61	54.08±3.04	63.60±2.72	74.16±2.70		
Height (m)	161.88±4.85	161.28±6.60	160.63±6.42	159.85±5.93	158.13±5.26	153.92±5.51	<0.001	
Weight (kg)	59.63±9.07	61.78±11.71	62.91±10.23	63.19±8.48	65.58±10.13	62.12±9.26	0.001	
BMI (kg/m^2)	22.77±3.43	23.71±3.97	24.40±3.87	24.75±3.18	26.21±3.79	26.28±4.17	<0.001	
CSA$_{IMAT}$ (cm^2)	3.00±1.70	3.36±2.18	4.26±2.33	5.54±2.17	8.26±3.50	11.06±4.56	—	0.001
CSA$_{muscle}$ (cm^2)	38.46±6.33	40.02±6.88	39.62±6.43	38.59±7.39	35.56±5.26	30.86±5.37	<0.001	0.174
IMAT% (%)	7.29±4.60	7.63±3.41	9.68±4.96	12.75±5.42	18.57±6.16	25.84±7.55	<0.001	0.071

Data are expressed as mean ± SD. P by Kruskal-Wallis test for changes across age groups. BMI, body mass index; IMAT, Intermuscular adipose tissue; CSA, cross-sectional area. IMAT% referred to CSA$_{IMAT}$ / (CSA$_{IMAT}$ + CSA$_{muscle}$) as fatty infiltration ratio of muscle.

Table 2 Paraspinal muscle and IMAT measurements across BMI subgroups in young (20–39 years), middle-aged (40–59 years) and elderly (60–79 years) group

Age (years)	BMI (kg/m^2)	CSA$_{IMAT}$ (cm^2)	CSA$_{muscle}$ (cm^2)	IMAT% (%)
20–39 (n=196)	Normal (n=125, 63.8%)	2.84±1.23	37.58±5.28	7.04±3.00
	Overweight (n=46, 23.4%)	3.39±1.27**	41.80±6.00***	7.57±2.89
	Obesity (n=25, 12.8%)	4.91±4.32***	44.65±9.88***	9.78±7.25*
40–59 (n=228)	Normal (n=118, 51.8%)	4.20±2.08	37.89±6.05	10.08±5.31
	Overweight (n=72, 31.6%)	4.96±2.12**	39.22±7.41	11.50±5.45*
	Obesity (n=38, 16.6%)	6.08±2.92***	43.37±6.40***	12.12±4.97*
60–79 (n=92)	Normal (n=25, 27.2%)	7.19±3.23	31.52±4.96	18.57±7.42
	Overweight (n=36, 39.1%)	8.59±3.39	34.83±5.40*	19.73±7.11
	Obesity (n=31, 33.7%)	11.00±4.42***	35.88±5.86**	23.10±6.88*

*P value <0.05, **P value <0.01, ***P value <0.001. P values were calculated using Kruskal-Wallis tests and LSD post-hoc correction. The normal BMI subgroup was defined as the reference group. BMI, body mass index; IMAT, Intermuscular adipose tissue; CSA, cross-sectional area. IMAT% referred to CSA$_{IMAT}$ / (CSA$_{IMAT}$ + CSA$_{muscle}$) as fatty infiltration ratio of muscle.

normal BMI subgroups for CSA$_{IMAT}$ and CSA$_{muscle}$. IMAT% showed similar trends in all age groups. The young and middle-aged group showed significant differences for CSA$_{IMAT}$ across overweight and normal BMI subgroups.

Correlation of measurement variables with age and anthropometric parameters

Lowess curve fitting indicated a nonlinear correlation between CSA$_{IMAT}$, IMAT%, and age. However, the association between CSA$_{muscle}$ and age was linear (*Figure 4*). CSA$_{IMAT}$, IMAT% increased with aging, whereas CSA$_{muscle}$ decreased with increasing age.

Correlation coefficients of measurement variables with age and anthropometric parameters are presented in *Table 3*. Strong positive associations of age with CSA$_{IMAT}$ and IMAT% were shown (r=0.656, P<0.01; r=0.714, P<0.01). A weak negative association between CSA$_{muscle}$ and age was observed (r=−0.265, P<0.01). We also found positive relations of BMI with CSA$_{IMAT}$ and CSA$_{muscle}$ (r=0.441, P<0.01; r=0.247, P<0.01) (*Table 3*). Interestingly, CSA$_{IMAT}$ was negatively associated with CSA$_{muscle}$ (r=−0.102, P<0.01).
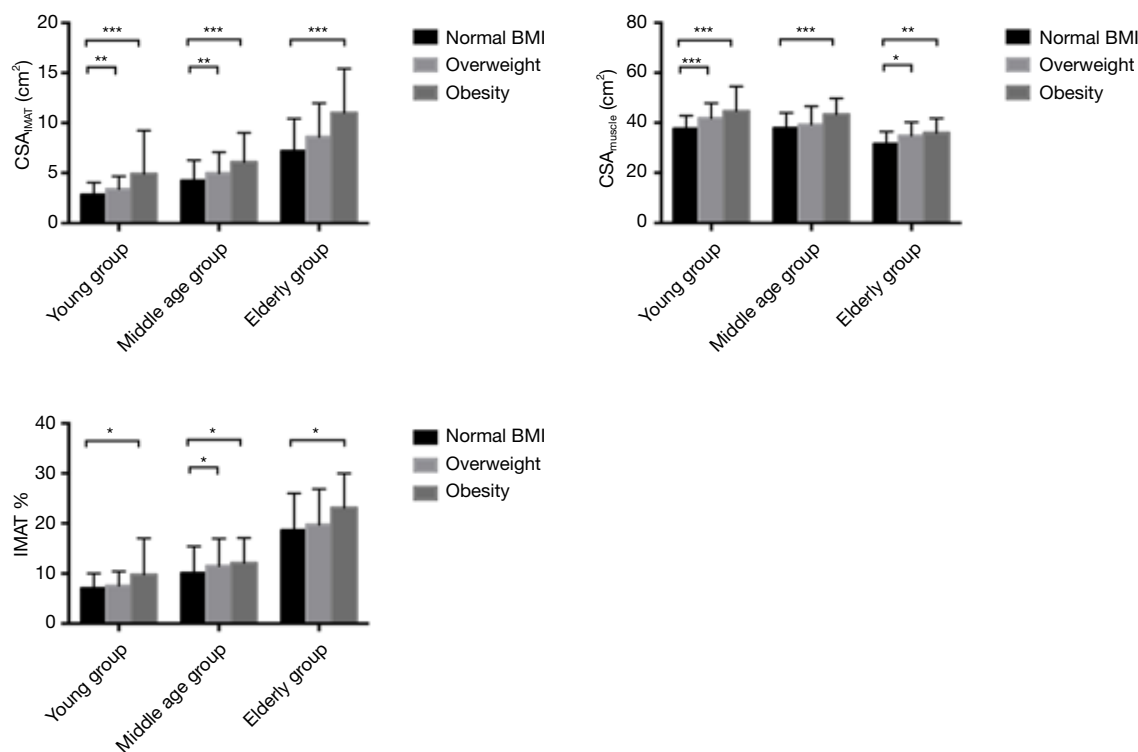
Figure 3 Comparisons of paraspinal muscle measurement and fat among BMI subgroups in young (20–39 years), middle-aged (40–59 years), and elderly (60–79 years) group. The normal BMI subgroup was defined as the reference group. *P value<0.05, **P value<0.01, ***P value <0.001. BMI, body mass index; IMAT, Intermuscular adipose tissue; CSA, cross-sectional area. IMAT% referred to CSA_{IMAT} / (CSA_{IMAT} + CSA_{muscle}) as fatty infiltration ratio of muscle.

Age-related differences in CSA_{IMAT}, CSA_{muscle}, and IMAT%

Table 4 lists the percentage change of measurements, adjusted for height and weight per decade over the age range of 21–79 years. Compared to muscle, CSA_{IMAT} showed a larger age-related difference (the percentage change of 20 to 79 years for CSA_{IMAT} +212.5% *vs.* CSA_{muscle} −17.1%). CSA_{muscle} showed a comparatively mild decrease, demonstrating a change of less than 20% between the ages of 20 and 79 years. Subjects aged between 20 and 39 years, showed only a 2.0% increase for CSA_{IMAT} and a slight 2.7% increase for CSA_{muscle} across a decade increase in age. Between 60–79 years, the percent change of CSA_{IMAT} and CSA_{muscle} per decade were prominently greater than that of the younger age ranges. CSA_{IMAT} also revealed significant change between 40–59 years compared with the 20–39 years group. The changes in IMAT% showed a similar trend to that observed with CSA_{IMAT}.

Discussion

In this study, we applied QCT imaging to quantify paraspinal muscles (multifidus and erect spinae muscle) and intermuscular adipose tissue at the 3rd lumbar vertebrae. This method was used to investigate age-related changes in fatty degeneration in paraspinal muscles. A total of 516 healthy Chinese women (21–79 years of age) took part in this study. Our results indicated that fatty infiltration in paraspinal muscles increased with age, while muscle loss might be associated with aging. We also found that fatty infiltration in paraspinal muscles increased with BMI in different age groups.

Our study showed that the fat infiltration ratio of combined multifidus and erector spinae muscle was 9.68%±4.96% for 40–49 years group and 25.84%±7.55% for 70–79 years group. A similar measurement conducted with MRI in a Japanese female population demonstrated
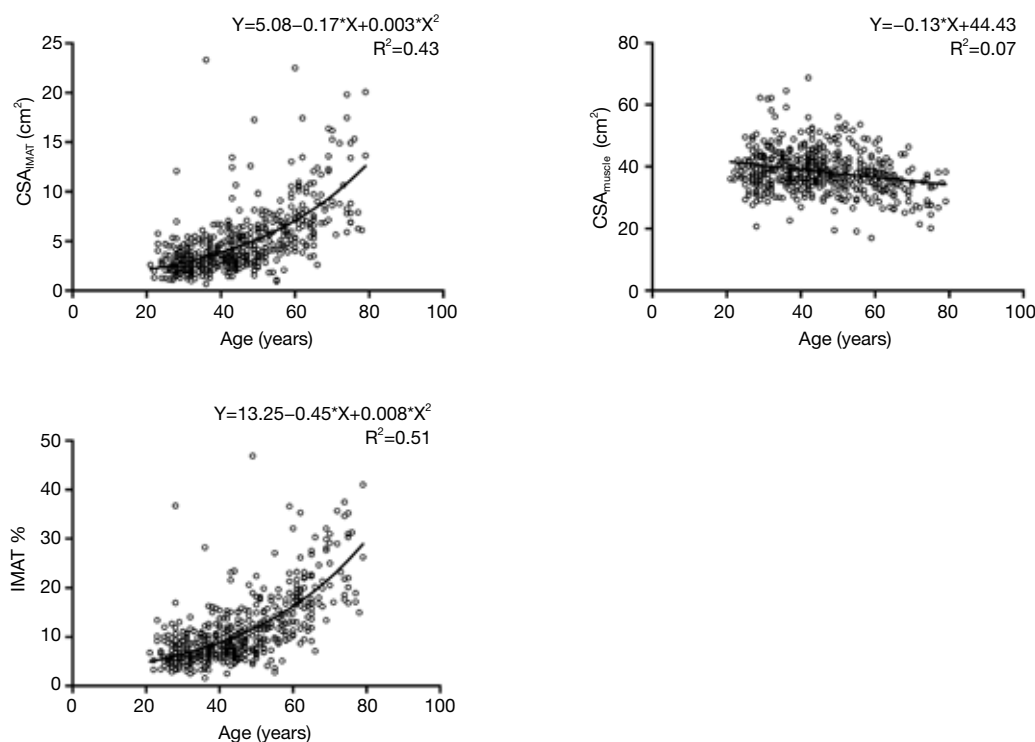
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Figure 4 Relationship of CSA_{IMAT}, CSA_{muscle}, and IMAT% to age among 516 healthy Chinese women. The solid line indicated a nonlinear or linear association between measurement results of paraspinal muscles and fat and age. Quadratic and linear regression equations and R2 values are shown.

Table 3 Spearman correlation coefficient between age, anthropometric parameters and measurement results of paraspinal muscles and IMAT

Coefficient	Age (years)	Height (m)	Weight (kg)	BMI (kg/m^2)	CSA_{IMAT} (cm^2)	CSA_{muscle} (cm^2)	IMAT% (%)
Age (years)	1.000	−0.248**	0.170**	0.287**	0.656**	−0.265**	0.714**
Height (m)		1.000	0.255**	−0.210**	−0.133**	0.358**	−0.216**
Weight (kg)			1.000	0.870**	0.368**	0.423**	0.231**
BMI (kg/m^2)				1.000	0.441**	0.247**	0.342**
CSA_{IMAT} (cm^2)					1.000	−0.102**	0.962**
CSA_{muscle} (cm^2)						1.000	−0.337**
IMAT% (%)							1.000

**P value <0.01. BMI, body mass index; IMAT, intermuscular adipose tissue; CSA, cross-sectional area. IMAT% referred to CSA_{IMAT} / (CSA_{IMAT} + CSA_{muscle}) as fatty infiltration ratio of muscle.

the fat infiltration ratio of separated erector spinae muscle at L3/L4 level was 6.7%±1.5% for <50 years group and 12.4%±3.8% for 70–79 years group. The same study also revealed the infiltration ratio of separated multifidus muscle was 6.5%±1.9% for <50 years group and 13.9%±5.4% for 70–79 years group (15). The inconsistency of fat filtration ratio values in the 70–79 age group between our findings and the trial above is unclear. However, according to Kalichman's paraspinal muscle scoring system (27) (grade 1, a normal muscle condition, fatty infiltration up to 10% of the muscle's CSA; grade 2, moderate muscle degeneration, 10–50% of fatty infiltration; and grade 3, severe muscle degeneration,

Table 4 Rate of change (%/decade) cross adulthood for CSA$_{IMAT}$, CSA$_{muscle}$, IMAT% by QCT with adjustment for height and weight

Variable	20–29 years (n=69), mean ± SD	%change 30–39 years (n=127)	%change 40–49 years (n=140)	%change 50–59 years (n=88)	%change 60–69 years (n=67)	%change 70–79 years (n=25)	%change 20–79 years	Absolute change between 20 and 79 years
CSA$_{IMAT}$ (cm^2)	3.44±0.28	+2.0	+21.1**	+28.2***	+42.9***	+38.0***	+212.5	+7.31
CSA$_{muscle}$ (cm^2)	38.96±0.67	+2.7	–1.5	–2.4	–8.7***	–8.0*	–17.1	–6.67
IMAT% (%)	7.95±0.59	–0.4	+22.5**	+30.0***	+41.5***	+39.7***	+213.5	+16.97

*P value <0.05, **P value <0.01, ***P value <0.001. BMI, body mass index; IMAT, intermuscular adipose tissue; CSA, cross-sectional area. IMAT% referred to CSA$_{IMAT}$ / (CSA$_{IMAT}$ + CSA$_{muscle}$) as fatty infiltration ratio of muscle.

>50% of fatty infiltration), a fat infiltration ratio of about 12% for Japanese 70–79 years group seems low. Another longitudinal study revealed the highest percentage of fat in multifidus muscle, measured by MRI at L4 and L5 level, was 28.8%±12.7% for baseline 40 years of age, 28.7%±11.9% for 45 years at follow up and 31.6%±13.0% for 49 years in Danish population (28). Compared to our study, the higher fatty infiltration of the multifidus muscle in Danish may be due to differences in ethnicity, detection methods, measurement sites, and target muscle. A previous study found quantifying differences in paraspinal muscle CSA between MRI and CT measurement (13). Previous studies showed that fatty degeneration of paraspinal muscles was more prominent in the lower lumbar level than the upper lumbar level (13,29). Furthermore, the target muscle also affects the interpretation of the study results. The multifidus muscle has two fiber directions; vertical and horizontal to the spinal axis, which can disperse the stress. On the contrary, the erector spinae muscles are mainly vertical to the spinal axis, bearing more stress than multifidus muscle. As such, the multifidus muscle displayed more fatty degeneration than the erector spinae muscles (29).

Concerning the degeneration of paraspinal muscles, most previous studies focused on the associations between paraspinal muscle size and low back pain, kyphosis, or osteoporosis fracture (3,17-20,30). Several studies mainly focused on applying the paraspinal muscle composition assessment to the elderly population (19,20,30). However, its application to young and middle-aged populations are not widely investigated. Only a few publications have evaluated muscle sizes and fatty infiltration of paraspinal muscles across the lifespan of healthy populations (29,31,32). However, no studies have reported on the reference data for paraspinal muscle degeneration of healthy people in China. CT and MRI are the gold standards for estimating muscle mass among numerous measuring techniques applied in

research and routine clinical practice (5). The majority of the above studies used MRI to measure muscle and fat CSA. To the best of our knowledge, our study is the first to present normative reference values of those parameters in healthy Chinese females.

Similar to previous studies, the paraspinal muscle size tended to decrease with age, while the fat infiltration rate increased with age (16,21,29). However, Crawford *et al.* reported a different trend in age-related muscle CSA change, where multifidus and erector spinae volume was age-independent in 80 healthy adult volunteers using MRI (31). The inconsistency of results between studies may be related to methodologic differences in the measurement methods (CT versus MRI) and parameters (CSA versus volume), targeted muscle groups, and study sample population.

In this study, we used a QCT-based method for the paraspinal muscles and infiltrated fat measurements, rather than HUs (Hounsfield Units). This is because HUs for segmentation and the measurement of muscle and infiltrated adipose tissue vary significantly across different studies (14). For muscle segmentation, different HU thresholds used in literature may not be very relevant, as in semi-automatic measurement procedures, initial threshold-based contours guide the operator and could be corrected if necessary. Compared to segmentation, differences in HUs have a significant impact on the quantification of adipose tissue found within the perimuscular deep fascia, such as the paraspinal muscles. The concern with using absolute CT thresholds stems from unaccounted deviations from the ideal water calibration of the CT scanner. The thresholds are also inconsistent across the literature (14,33).

For this reason, the separation of intermuscular and intramuscular adipose tissue components is of interest. Some studies have suggested techniques based on in-scan calibration phantoms (34,35). In this study, all CT scans

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were acquired with a QCT calibration phantom. The calculation of the paraspinal muscle and infiltrated adipose tissue was based on the CT calibration data, derived from the phantom scanned simultaneously with subject imaging. However, the sensitivity of the calibration method relative to the threshold selection has not been reported and needs further studies. Another issue is that the cross-sectional CT imaging would be affected by partial volume effects in measurements of muscle and adipose tissue. Thicker slices reduce noise and are adequate when the muscle volume or density is of primary interest. For a more advanced analysis of the adipose tissue distribution, a higher spatial resolution is required, and a slice thickness of 2 mm is preferable (14).

Expressed as absolute change between 20–79 years, or decade percentage change, CSA_{IMAT} both showed more significant age-related differences than CSA_{muscle}. Notably, CSA_{IMAT} was negatively associated with CSA_{muscle}, which indicates that muscle infiltration might partly cause muscle loss. This phenomenon requires further investigation. A study conducted by Dorien reported a higher amount of fat infiltration in the lumbar muscles without differences in muscle CSA in adults with continuous chronic back pain, compared to recurrent low back pain (17). Fat infiltration of skeletal muscle, either solely or along with muscle mass loss, appears to contribute to age-related depletion in skeletal muscle function.

Our results demonstrated that people over 40 years showed more prominent changes with age for CSA of IMAT and fatty infiltration. The percentage change per decade identified 40 years as the potential age, where a significant change in paraspinal muscle composition occurs across the life span of Chinese females. The peak of muscle mass is achieved in early adult life, followed by a progressive decline after the age of 40 (10,36). After the age of 50, the decline of muscle mass becomes more substantial, proceeding at a rate of less than 3% per year (10,37). However, the available data was mostly based on whole-body DXA measurements, which are mostly different from the assessment tools in the study. It is noteworthy that there is no data available on validated measurements of muscle health and its relationship with gender and ethnicity across adulthood. Our study demonstrates cross-sectional age-related changes in paraspinal muscle in females aged 20 to 79 years. These changes were examined on a per-decade basis. The study indicates the commencement of lumbar muscle decline in females in the 4th decade. These results are earlier than other reports in the literature, where muscle decline

occurred after the age of 50 years. Little is known about normative degeneration of the lumbar paraspinal muscles. Most paraspinal muscle relevant studies examine patients with low back pain or severe spine degeneration. Our observation would contribute to the difficulty in estimating the age-related decline in skeletal muscle in adulthood due to incomplete data sets across age ranges. However, the findings of this study require validation with additional cohorts and further studies.

In our study, obesity groups revealed significantly greater fatty infiltration, compared to normal BMI groups across adulthood, while positive relationships were observed between BMI with CSA_{IMAT} and CSA_{muscle}. A clear correlation between obese and overweight subgroups with higher CSA_{muscle} (*Figure 3*) is consistent with previous reports, where obese and overweight adults often have a higher muscle mass compared to their non-obese peers (38,39). These findings may be due to the extra loading of adipose tissue seen in both subgroups, acting as a training stimulus on skeletal muscle (40). However, our findings demonstrated that body size has a more significant influence on intermuscular fat deposition than increasing muscle mass. Primarily, a higher BMI (often defined as more obese) would introduce more significant muscle fatty infiltration.

In summary, the consensus is that obese adolescents exhibit lower relative muscle quality, despite displaying a larger muscle size. Valentin *et al.* examined bilateral lumbar erector spinae, multifidus, rectus abdominis, and psoas muscles of twenty-four healthy adults using T1-weighted axial MRI. They reported age and BMI as relevant factors for paraspinal extensor muscle volume (32). In contrast, Crawford *et al.* showed no significant correlation between BMI and fat signal fraction in multifidus and erector spinae (31). The discrepancy among these studies may be due to methodological differences.

There are several limitations to our study. First, study subjects in this study were exposed to radiation from CT scans to measure the fatty infiltration of paraspinal muscles. However, the CT data used in the current study were obtained from the QCT results of an ongoing spine and knee degeneration and the CASH study. Therefore, the study participants were not subjected to additional radiation exposure. Second, the CSA measurements of paraspinal muscles and IMAT were isolated to the L3 vertebral level, instead of analyzing the whole volume of paraspinal muscles. Third, only multifidus muscle and erector spinae muscle were examined, excluding psoas major muscle in this study. Fourth, data from the male population was

not examined. Although more than 500 participants were included in the present analysis, the study population was recruited exclusively from Beijing. Therefore, the data may not be representative of the general female population, as it does not account for women of rural areas or other ethnic populations.

Furthermore, the body height of the study population was lower than the average value of female residents in Beijing. These findings were particularly observed in the young group. These results may be due to a selection bias, which would have affected data interpretation. Last, the fatty infiltration of the paraspinal muscles would be affected by the lumbar degeneration. However, as participants in this study were healthy and without severe degeneration, we consider the study population as representative of the respective age groups, demonstrating age-related physiological changes.

In conclusion, our study provides a normal reference data of fatty degeneration of paraspinal muscles for healthy, Chinese adult women. Future studies are required to investigate changes of paraspinal muscle morphology and composition with clinical implications for physical function and mortality.

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Footnote

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Conflicts of Interest: Both authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/qims-19-835). The special issue "Body Composition Imaging" was commissioned by the editorial office without any funding or sponsorship. The authors have no other conflicts of interest to declare.

Ethical Statement: The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Institutional Review Board of Beijing Jishuitan Hospital. Informed consent was obtained from each subject.

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