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ORIGINAL ARTICLE

Body compositions differently contribute to BMD in different age and gender: a pilot study by QCT

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Abstract

Summary The study was to investigate the correlation between body compositions and bone mineral density (BMD) and to evaluate the body composition contribution to BMD. In male, LM showed positive effect on BMD. In female, SAT showed positive, and FM and F/L showed negative effect on BMD.

Purpose The purpose of the study was to investigate the correlation between body compositions and bone mineral density (BMD) performed by quantitative computed tomography (QCT), and to evaluate the body composition contribution to BMD.

Methods Three hundred ninety-four participants, including 122 male (31%) and 272 female (69%), were divided into groups by gender, age, and BMD. BMD and body compositions [including fat mass (FM), lean mass (LM), bone mass/lean mass ratio (B/L), fat mass/lean mass ratio (F/L), total adipose tissue (TAT), subcutaneous adipose tissue (SAT), visceral adipose tissue (VAT)] were retrospectively compared among groups using one-way ANOVA or *t* test. A stepwise multivariate analysis was used to evaluate the body composition contribution to BMD and produced models.

Results In male, BMD got decreased with age ($P < 0.05$). LM increased before 30–49 years, then decreased ($P < 0.05$). TAT and SAT decreased with age ($P < 0.05$). LM in OP group was lower than those in the other two groups ($P < 0.05$). Through stepwise multivariate analysis, LM firstly got into model 1 (M1, $\beta = 0.589$). In female, BMD, LM TAT, and VAT were increased before 30–49 years, then decreased ($P < 0.05$). FM and F/L increased with age ($P < 0.05$). SAT decreased with age ($P < 0.05$). FM and F/L in OP group were higher than those in other groups. LM, B/L, TAT, and SAT in the OP group were lower than those in the other groups ($P < 0.05$). SAT entered the M1 with a maximum β value ($\beta = 0.584$).

Conclusions BMD and body compositions displayed different characteristics with age. In male, LM showed positive effect on BMD. In female, SAT showed positive, and FM and F/L showed negative effect on BMD.

Keywords Body compositions · Bone mineral density · Osteoporosis · QCT

Xueli Zhang and Ting Hua contributed equally to this study and should be considered co-first authors.

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Introduction

As lifespan increase, osteoporosis (OP), obesity, and sarcopenia are becoming key clinical feature for old age. The relationship between body compositions and bone mineral density (BMD) is complex and controversial. OP is a metabolic disorder disease of skeleton resulting from changing in BMD, bone geometry, and microstructure. It increases susceptibility to fraction, which is one of the major health problems in older adults. In addition to some influence factors for BMD, such as age, sex hormones, and body mass index (BMI), several cross-sectional studies have demonstrated significant association between body compositions and bone mass [1]. Aging usually leads to a loss of lean mass (LM) and an increase of adipose tissue, but how body components impact on BMD is unknown [2], especially in different age and genders. Adipose tissue has direct or indirect effects on bone mass. On the one hand, adipose tissue increases bone mass due to physical weight bearing. On the other hand, it might influence BMD through the production of hormones and adipokines by adipocytes. Some epidemiological studies have demonstrated association between LM and BMD in both genders [3, 4]. Quantification of BMD has been used as the main method to diagnose OP. Dual energy X-ray absorptiometry (DXA) and quantitative computed tomography (QCT) are the most common tools for measuring BMD presently. Areal BMD estimates using DXA are currently considered a gold standard for making a diagnosis of OP and for predicting fracture risk [5]. However, it has been shown to be only a partial predictor of fracture risk. This may be due to the fact that two-dimensional measurements do not fully reflect the distribution of bone mass. QCT not only can determine in three dimensions the true volumetric BMD (vs BMD) at any skeletal site but also can measure total adipose tissue (TAT) of the abdomen enabling differentiation of subcutaneous adipose tissue (SAT) from visceral adipose tissue (VAT), which is considered a gold standard for assessing adipose and muscle distribution [6].

The aim of the study was to investigate the correlation between body compositions and BMD performed by QCT, and the contributions of body compositions to BMD were evaluated in different age and gender groups.

Materials and methods

Study populations

The current study included 272 female (69%) and 122 male (31%) aged 20–86 years (mean age 53.7 ± 19.5 year-old). All 394 participants underwent QCT examination because of low back pain (including chronic lumbar spondylosis, discogenic pain) from Jan. 2016 to Feb. 2017 in our hospital. The exclusion criteria include compression fracture of lumbar vertebrae that affect measurement results, pregnancy, history of drug therapy (anti-osteoporosis drugs, estrogen replacement therapy, glucocorticoids), and history of malignancy radiotherapy or chemotherapy. None of the participants had a renal failure, hyperthyroidism, hyperparathyroidism, chronic colitis, leukemia, or chronic arthritis. Ethics committee of our institution approved the study, and informed consent was obtained from all individual participants included in the study.

BMD measurement

All subjects underwent CT scan of lumbar vertebrae from L1 to L3 with a 64-slice CT scanner (Light speed VCT, GE medical systems, USA) and with a solid-state CT calibration phantom (Mindways Software Inc., Austin, TX, USA) closely under every participant low back simultaneously. QCT examination was performed by the following parameters: tube voltages 120 kV, tube current 125 mAs, slice thickness of 1.25 mm, and a matrix size of 512 × 512. Images were transferred to a QCT workstation and analyzed using the three-dimensional (3D) spine function version 5.10 of Mindways QCT pro software (Mindways Software Inc., Austin, TX, USA). Regions of interest (ROI) were placed in the central part of L1–L3 vertebral body on axial, sagittal, and coronal images (Fig. 1a). The ROI margin was greater than 3 mm distal the lumbar borders to avoid partial volume effect from the cortical bone. The area of ROI about 250–350 mm^2 is as large as possible within the boundary of choice. BMD value was the mean BMD of L1–L3 vertebral body. Each parameter was calculated individually by three radiologists, and the average of each parameter was used to be the final one. Subjects were categorized into three groups based on BMD: normal (BMD ≥ 120 mg/cm^3), osteopenia (80–120 mg/cm^3), and OP (≤ 80 mg/cm^3) [7].

Body compositions measurement

Body composition parameters were acquired by QCT with 1.25-mm slice thickness on the midsagittal image of L3 vertebral body, which completed synchronization with the BMD examination. To calculate different body compositions easily, the voxels within the slice were separated into color-coded objects containing adipose tissue [− 190 to − 30 hounsfield units (HU)], muscles (0 to 100 HU), and bone (≥ 145 HU) [6]. A closed contour was drawn around the abdomen, created by temporarily removal of the skeletal muscle, intestine, vertebra, and others due to the value of density not in the range of adipose tissue. The subcutaneous adipose tissue (SAT) was defined as adipose tissue outside of the range manually drawn around the abdominal wall with value of density in the range of adipose tissue (− 190 to − 30 HU) (Fig. 1b). The visceral

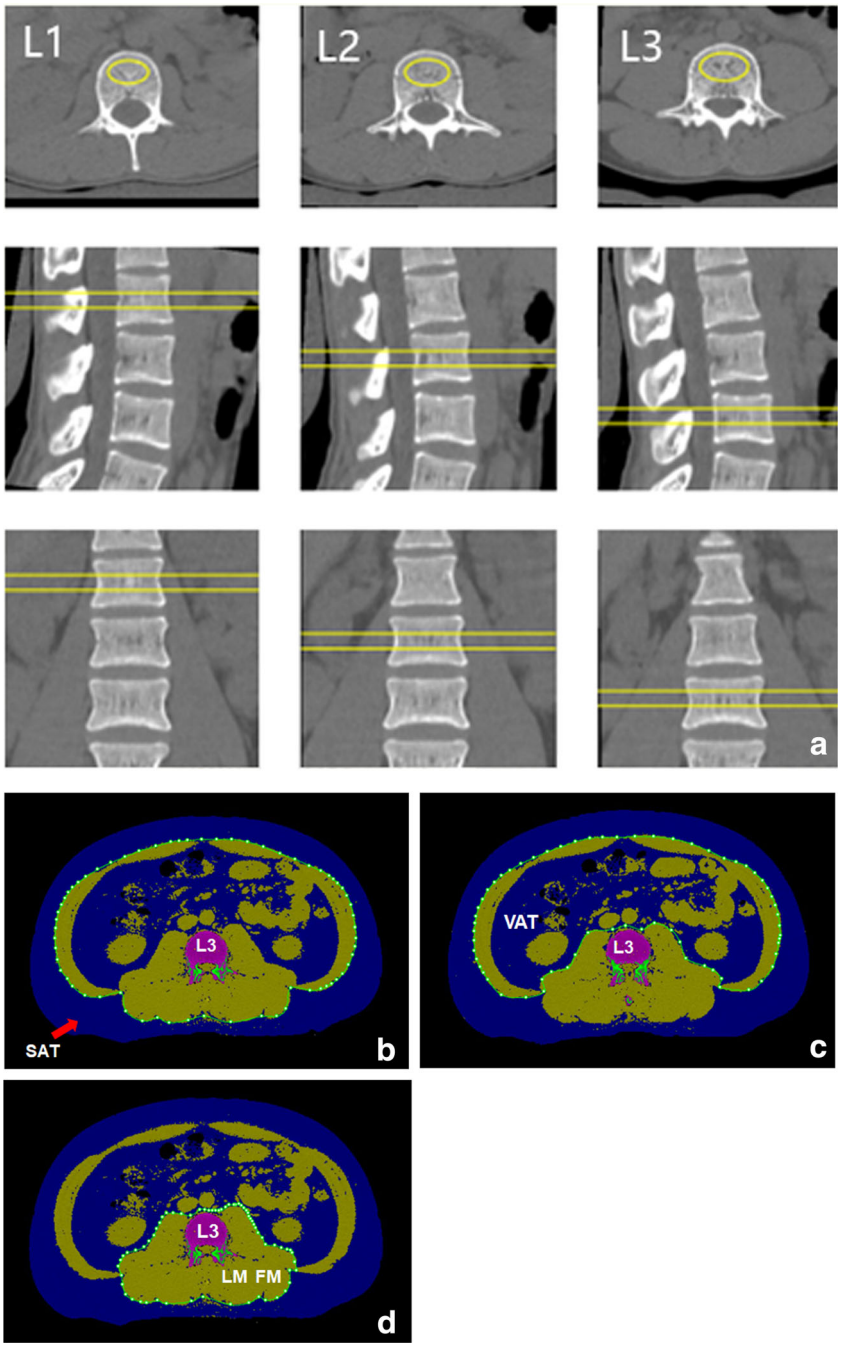

Fig. 1 The measurement methods of BMD, SAT, VAT, FM, and LM. **a** The measurement of L1–L3 BMD by QCT on axial, coronary, and sagittal plane. **b** The measurement of SAT was performed outside of the range manually drawn around the abdominal wall at the level of L3 midplane. **c** VAT was measured within the range manually drawn around the abdominal wall and lumber muscles. **d** The measurement of LM and FM was performed within the range of muscle or adipose tissue manually drawn within fascial borders of lean mass (psoas and paraspinal muscles) at the level of L3 axial midplane, respectively

adipose tissue (VAT) was defined as adipose tissue manually within the range drawn around the abdominal and lumber muscles. The total adipose tissue (TAT) was computed as the sum of SAT and VAT (Fig. 1c). The fascial borders of lean mass (psoas and paraspinal muscles) were traced manually and were segmented out of the image. The voxels with the value of density in the ranges of muscle or adipose tissue were defined as lean mass (LM) and fat mass (FM), respectively (Fig. 1d). Thus, the fat mass/lean mass ratio (F/L) and B/L (bone mass/lean mass ratio) were calculated automatically.

Statistical analysis

The analyses were performed by SPSS 20.0 (SPSS, Chicago, IL, USA). Statistical description of the quantitative variables was presented as mean ± standard deviation (SD). Total participants were categorized into four groups based on ages (< 30, 30–49, 50–69, > 70 years old) to explore how the BMD and body compositions change with age. The variables were compared between male and female in the same age group using *t* test. The comparison of BMD and body compositions among different age and BMD groups were conducted

through one-way ANOVA. A stepwise multivariate analysis was used to evaluate the contribution of body composite indices to BMD in male and female, respectively, with BMD as the dependent variable, whereas FM, LM, F/L, B/L, TAT, VAT, and SAT as independent variables, and standardized coefficients were reported. A P value less than 0.05 was considered statistically significant.

Results

The characteristics of BMD and body compositions in male

The value of BMD and body compositions of 394 subjects in different genders and age are summarized in Table 1. The demographic characteristics were compared among age groups (< 30 years as control group). In male ($n = 122$, 31%), BMD got progressively decreased with age. LM was increased before 30–49 years and then gradually decreased. Compared to those in control group, both parameters were significantly decreased in 50–69 years, > 70 years group ($P = 0.000$, for all). FM got increased with age, but no significant difference was found among four age groups ($P > 0.05$), and so did F/L and B/L (both $P > 0.05$). Compared to those in control group, TAT and SAT in other groups (30–49 years, 50–69 years, > 70 years) got significantly decreased (for TAT, $P = 0.021$, $P = 0.001$, and $P = 0.001$, for SAT, $P = 0.002$, $P = 0.000$, and $P = 0.000$, respectively). There was no statistically significant difference for VAT among four age groups ($P > 0.05$).

The characteristics of BMD and body compositions in female

In female ($n = 272$, 69%), BMD and LM got increased gradually before 50 years and then rapidly decreased. FM was progressively increased with age. They all showed significant difference in 50–69 years old group and > 70 years old group when compared with those in control group (for BMD, both $P = 0.000$; for LM, $P = 0.049$, $P = 0.000$; for FM, both $P = 0.000$). F/L got significantly increased in other three age groups when compared with those in control group ($P = 0.038$, $P = 0.000$, $P = 0.000$, respectively). The changing of B/L displayed no statistical difference among four age groups ($P > 0.05$). TAT and VAT were increased before 30–49 years and then significantly decreased in 50–69 years group and > 70 years group when compared with those in control group (for TAT, both $P = 0.000$; for VAT $P = 0.020$, $P = 0.000$, respectively). SAT was gradually decreased with age, and a significant difference was obtained in 50–69 years groups and > 70 years group when compared with those in control group ($P = 0.002$, $P = 0.000$, respectively).

Table 1 The variables of body compositions were compared among age groups in male and female

Variables		Male				Female			
	Age	< 30	30–49	50–69	> 70	< 30	30–49	50–69	> 70
	n	36	50	57	25	36	46	86	58
BMD (mg/cm^3)		167.21 ± 34.22	154.52 ± 30.45	119.65 ± 24.43*	116.15 ± 21.61*	170.61 ± 30.19	172.84 ± 30.15	94.67 ± 30.28 †#	61.91 ± 30.27†#
FM (g)		1.01 ± 0.34	1.02 ± 0.31	1.04 ± 0.24	1.36 ± 0.25	0.74 ± 0.19	0.86 ± 0.33	1.25 ± 0.26†	1.56 ± 0.28†#
LM (g)		12.94 ± 2.13	13.04 ± 2.45	9.88 ± 1.59*	9.30 ± 1.58*	9.12 ± 1.54	10.11 ± 2.97#	8.04 ± 2.18†#	7.16 ± 1.77†
F/L		0.09 ± 0.04	0.08 ± 0.03	0.11 ± 0.03	0.11 ± 0.05	0.08 ± 0.02	0.09 ± 0.03†	0.16 ± 0.04† #	0.22 ± 0.04†
B/L		0.06 ± 0.01	0.06 ± 0.01	0.07 ± 0.02	0.06 ± 0.01	0.08 ± 0.02	0.08 ± 0.01#	0.06 ± 0.02	0.08 ± 0.02
TAT (g)		563.12 ± 74.21	459.91 ± 61.3	347.12 ± 52.51*	273.30 ± 50.12*	424.19 ± 60.21#	476.96 ± 69.61	295.51 ± 49.71†	268.23 ± 42.72†
VAT (g)		208.64 ± 24.91	215.73 ± 34.42	216.31 ± 32.02	159.74 ± 26.60	181.83 ± 19.47	184.29 ± 34.73	146.63 ± 23.24†#	145.72 ± 23.44†
SAT (g)		354.53 ± 48.63	244.24 ± 25.23*	124.76 ± 29.65*	113.32 ± 20.16*	309.35 ± 25.12	285.91 ± 22.23#	148.92 ± 32.15†	126.86 ± 24.82†

All data were mean ± SD

*$P < 0.05$ vs < 30 years group in male

†$P < 0.05$ vs < 30 years group in female

#$P < 0.05$ vs male group in the same age group

The comparison of BMD and body compositions between male and female

BMD in female was significantly lower than that in male in 50–69 years group and > 70 years group ($P = 0.003$, $P = 0.001$, respectively) (Fig. 2a). Female had higher FM than male in 50–69 years and > 70 years group; however, only in > 70 years group the difference was statistically significant ($P = 0.001$) (Fig. 2b). LM in male was higher than that in female in each age group, but a significant difference was showed only in 39–49 years group and 50–69 years group ($P = 0.001$ and $P = 0.002$, respectively) (Fig. 2c). F/L in female was significantly higher than that in male in 50–69 years group ($P = 0.001$) (Fig. 2d). The B/L and SAT in female were higher than those in male in the 30–49 years group ($P = 0.000$ and $P = 0.017$, respectively) (Fig. 2e, h). TAT in male was higher than that in female in < 30 years group ($P = 0.016$) (Fig. 2e, f). VAT in female was lower than that in male in 50–69 years group ($P = 0.000$, Fig. 2g).

The comparison of body compositions in different BMD groups in male

The demographic of body compositions was compared among normal group, osteopenia group, and OP group in male (Table 2). FM was higher in OP group than that in normal group and osteopenia group with no significant difference ($P > 0.05$). The results showed that LM in OP group was lower than that in osteopenia group ($P = 0.045$) and in normal group ($P = 0.048$). F/L presented increase with the decrease of BMD (osteopenia group vs normal group, $P = 0.034$; OP vs normal group, $P = 0.000$; OP group vs osteopenia group, $P =$

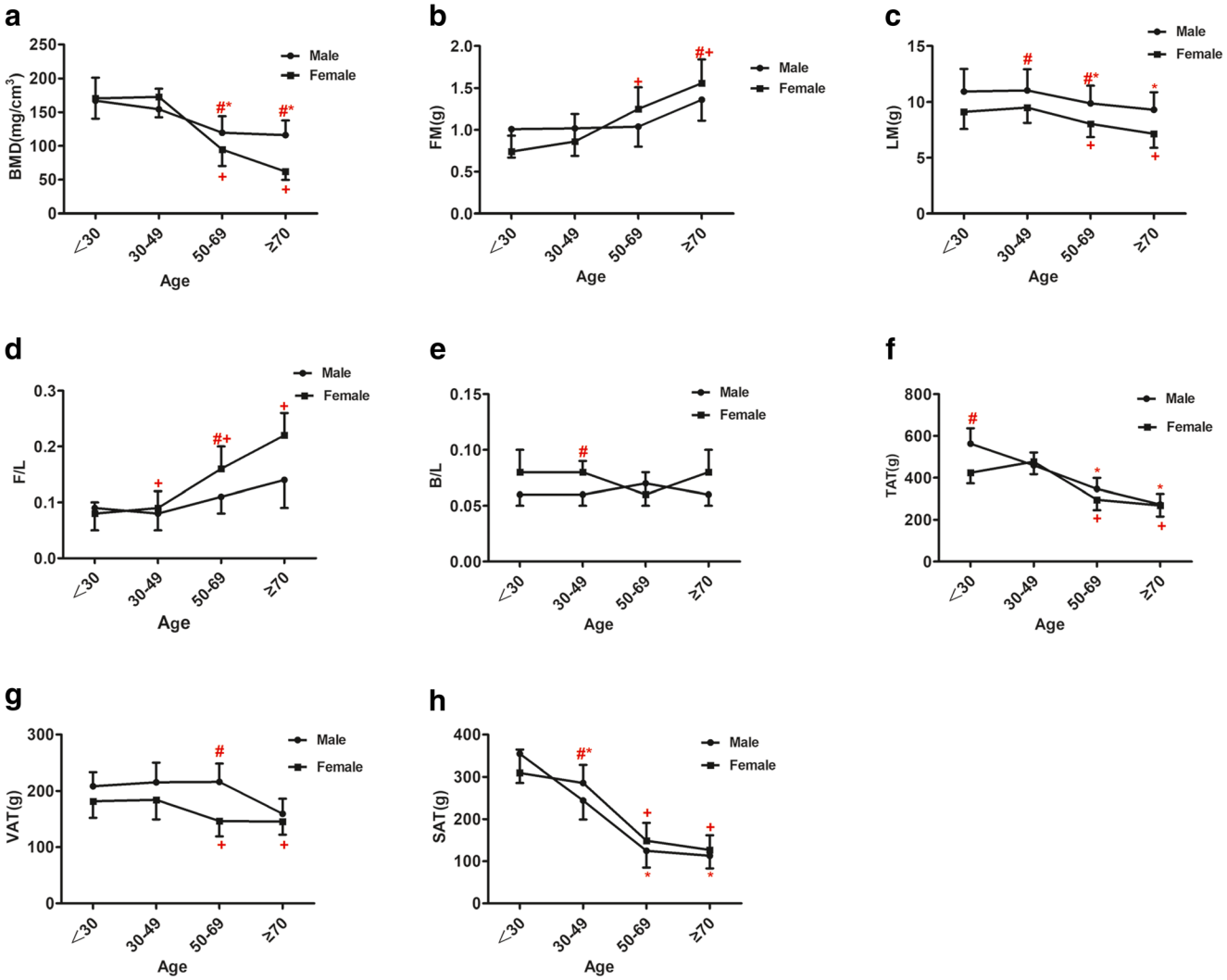

Fig. 2 The comparison of BMD and body compositions in different age and genders. * $P < 0.05$ vs that in < 30 years group in male. + $P < 0.05$ vs that in < 30 years group in female. # $P < 0.05$, the male vs female in the same age group. **a** The change of BMD with age in male and female groups. **b** The FM got gradually increased with age in male and female. **c** The change of LM in different age and gender groups. **d** The change of F/L with age in both genders. **e** The change of B/L with age in both genders. **f** The change of TAT with age in male and female. **g** The change of VAT with age in male and female. **h** The change of SAT with age in male and female

Table 2 The difference analysis between BMD and body compositions in male

Variables	Normal	Osteopenia	OP
FM (g)	1.02 ± 0.37	1.26 ± 0.60	1.60 ± 0.42
LM (g)	11.86 ± 2.54	10.12 ± 2.40	8.20 ± 1.56*†
F/L	0.09 ± 0.32	0.12 ± 0.04*	0.21 ± 0.10*†
B/L	0.07 ± 0.01	0.06 ± 0.02	0.04 ± 0.02*
TAT (g)	460.53 ± 217.15	339.36 ± 182.19	448.43 ± 68.87
VAT (g)	208.69 ± 99.42	193.39 ± 114.16	269.23 ± 17.96
SAT (g)	251.88 ± 76.10	138.82 ± 56.12	175.87 ± 93.90

All data were mean ± SD

*$P < 0.05$ vs normal group

†$P < 0.05$ vs osteopenia group

Table 3 The difference analysis between BMD and compositions in female

Variables	Normal	Osteopenia	OP
FM (g)	0.90 ± 0.39	1.29 ± 0.65*	1.41 ± 0.57*
LM (g)	8.96 ± 2.14	7.84 ± 2.66	7.25 ± 1.40*†
F/L	0.11 ± 0.07	0.14 ± 0.07*	0.20 ± 0.09*†
B/L	0.08 ± 0.02	0.06 ± 0.02*	0.05 ± 0.03*†
TAT (g)	386.39 ± 92.20	290.74 ± 116.53*	268.81 ± 94.72*
VAT (g)	141.11 ± 66.53	135.23 ± 54.48	147.46 ± 55.72
SAT (g)	232.12 ± 112.04	157.51 ± 78.54*	121.14 ± 55.75*

All data were mean ± SD

*$P < 0.05$ vs normal group

†$P < 0.05$ vs osteopenia group

0.002), and B/L in OP group showed significant decrease when compared to that in normal group ($P = 0.017$). No significant difference was found in TAT, VAT, and SAT among three groups ($P > 0.05$).

The comparison of body compositions in different BMD groups in female

Compared to that in normal group, FM showed significant increase in OP group ($P = 0.000$) and in osteopenia group ($P = 0.000$). LM was decreased with the decline of BMD (OP group vs normal group, $P = 0.010$; OP group vs osteopenia group, $P = 0.006$). F/L presented significant increase with the decline of BMD (osteopenia group vs normal group, $P = 0.006$; OP vs normal group, $P = 0.000$; OP group vs osteopenia group, $P = 0.004$), but B/L presented decrease with the decline of BMD (osteopenia group vs normal group, $P = 0.001$; OP group vs normal group, $P = 0.000$; OP group vs osteopenia group, $P = 0.047$). Both TAT and SAT showed similar trend with the decrease of BMD. They went down firstly and then increased (OP group vs normal group, both $P = 0.000$; osteopenia group vs normal group, both $P = 0.000$, respectively), and no significant difference was found in VAT among three groups ($P > 0.05$) (Table 3).

Multiple regression analysis of BMD and body compositions

The results of multiple regression analysis with body compositions as independent variables (X_1: FM, X_2: LM, X_3: F/L; X_4: B/L, X_5: TAT, X_6: VAT, X_7: SAT) and BMD as the dependent variable (Y) are shown in Table 4 (male) and in Table 5 (female).

In male, LM was the first variable to enter into the model 1 (M1) and revealed a significant positive contribution to BMD in all models. The β value of LM ($\beta = 0.589$) was the greatest in all indices. Then F/L got into the model 2 (M2, $\beta = -0.394$), B/L into the model 3 (M3, $\beta = 0.240$), and SAT into the model 4 (M4, $\beta = 0.157$). Other indices such as FM, TAT, and VAT had no significant effects on BMD in each model, so they were removed from models and regression equation. The value of R^2 represented expository power of the model, and it was the highest in M4 that illustrated the model 4 was the best fitting effect on BMD. The regression equation was $Y = 60.835 + 0.589\ X_2 - 0.394\ X_3 + 0.240\ X_4 + 0.157\ X_7$.

In female, SAT entered into the M1 firstly with a maximum β value ($\beta = 0.484$) and showed positive regression coefficients to BMD in all models. Then F/L entered into the M2 ($\beta = -0.397$), and B/L ($\beta = 0.284$), FM ($\beta = -0.138$), and LM ($\beta = 0.211$) entered into the models of M3, M4, and M5 in sequence. The R^2 value was highest in M5. The regression equation was $Y = 57.540 + 0.484\ X_7 - 0.397\ X_3 + 0.284\ X_4 - 0.138\ X_1 + 0.221\ X_2$.

Table 4 Stepwise multivariate analysis of BMD and body compositions in male

Model		Standardized β	t	P value	F	R^2
M1	Constant	50.442	4.245			
	LM	0.589	7.955	0.000	63.272	0.347
M2	Constant	42.851	6.964			
	LM	0.401	5.242	0.000	51.741	0.467
	F/L	− 0.394	− 5.157	0.000		
M3	Constant	49.814	2.021			
	LM	0.518	6.348	0.000	41.015	0.513
	F/L	− 0.299	− 3.792	0.000		
	B/L	0.240	3.299	0.001		
M4	Constant	60.835	2.451			
	LM	0.421	4.569	0.000	32.833	0.531
	F/L	− 0.339	− 4.241	0.000		
	B/L	0.224	3.112	0.002		
	SAT	0.157	2.134	0.035		

Table 5 Stepwise multivariate analysis of BMD and body compositions in female

Model		Standardized β	t	P value	F	R^2
M1	Constant	63.661	8.023	0.000		
	SAT	0.484	9.117	0.000	83.112	0.235
M2	Constant	57.596	7.941	0.000		
	SAT	0.401	8.226	0.000	84.525	0.385
	F/L	− 0.397	− 8.124	0.000		
M3	Constant	56.054	6.881	0.000		
	SAT	0.392	8.437	0.000	72.032	0.445
	F/L	− 0.428	− 9.154	0.000		
	B/L	0.248	5.414	0.000		
	Constant	65.317	11.823	0.000		
M4	SAT	0.395	8.548	0.000	55.597	0.453
	F/L	− 0.322	− 4.523	0.000		
	B/L	0.230	4.947	0.000		
	FM	− 0.138	− 1.983	0.048		
M5	Constant	57.540	5.109	0.000		
	SAT	0.357	7.563	0.000	47.784	0.472
	F/L	− 0.102	− 1.017	0.310		
	B/L	0.221	4.824	0.000		
	FM	− 0.353	− 3.604	0.000		
	LM	0.211	3.081	0.002		

Discussion

Recently, QCT was described as a new tool for measurement of BMD. The approach is convenient for assessment of BMD during routine abdominal CT scans, especially for those who have an increased risk of fracture. A study showed significant difference in OP detection rates between DXA and QCT which provided clinical evidence that QCT had a greater diagnostic sensitivity than DXA [8]. Moreover, QCT permits the detailed assessment of abdominal adipose tissue and also can provide valid measurement of skeletal muscles [7].

The results showed that BMD decreased slowly with aging in male. It is mainly due to the age-related bone mass reduction. In female, BMD increased gradually before 30–49 years and then got decreased rapidly. The difference in BMD change between female and male in 50–69 years group and > 70 years group may be associated with the sharp decrease of estrogen levels in postmenopausal female. The effect of estrogen deprivation occurring in menopause caused a marked stimulation of bone resorption and a rapid bone loss which is central for the onset of postmenopausal osteoporosis. FM increased with age in male and female. Marcus et al. [9] reported that intramuscular fat deposition was associated with metabolic deficits and lack of exercise in the elderly. The increasing adipose with aging was reported in both bone marrow and muscles, and adipose infiltration was also observed in nerves and capillaries [9]. Our previous report also showed that the pathological basis of bone marrow fat accumulation in OP model rabbits was manifested as the number increase of bone marrow adipocytes in early stage and concomitant volume increase later on [10]. Aging usually leads to a loss of LM and increases FM, but there remain uncertainties about how body components changes, especially fat mass changes throughout a person's lifespan. In female, F/L showed increase with age that may be due to the increase of FM and the decrease of LM, simultaneously. B/L did not show a statistical difference among age groups that is probably related to that both BMD and LM decreased with age.

Based on BMD measurement, the study had demonstrated that FM was higher in OP and osteopenia group than that in normal group both in male and female. The relationship between FM and BMD is still complex and controversial. A few studies indicated that in postmenopausal women, FM display protective effects toward BMD [3]; however, many studies suggested that FM may be detrimental for BMD, which reinforcing the findings of our study. Zhu et al. [11] reported that the increasing of marrow adipose tissue and marrow fibrosis may be reduced bone marrow perfusion which has a role of osteoporosis development in the early stage. LM had been previously demonstrated to be the strongest predictor of BMD in both genders. Likewise, our results showed that LM in normal group was significantly higher than that in OP group. The mechanism for this may be that the greater mass provided mechanical loading on the skeleton, which prompted the osteocytes to send a signal that either increases the activity of osteoblasts or decreases the activity of osteoclasts [12]. Physical inactivity leads to a decrease of the number and the size of muscle fibers due to muscle cell apoptosis and reduced mechanical stimulation [13]. Ahedi et al. [14] reported a reduction in the osteogenic effect resulting from minor mechanical stimulation imposed on the BMD by reducing the muscle mass and muscle function due to physical inactivity. Moreover, it has been widely shown that increased muscle mass is related to increase of BMD and a reduction in vertebral fracture risk [15]. F/L was higher in OP group than that in osteopenia and normal groups, which was mainly caused by the reduction of LM and increase of FM. B/L in osteopenia group was less than that in normal group. It implied that the BMD reduced faster than LM in the early stage of OP and then both get reduced homogenously. The relationship between abdominal adipose tissue and BMD is undefined. TAT and SAT got decreased and then increased with the decrease of BMD. Visceral adipocytes show higher lipogenic and lipolytic activities and produce more proinflammatory cytokines, while subcutaneous adipocytes are the main source of leptin and adiponectin [14].

Through above analysis, it showed that there existed a correlation between BMD and body compositions, but it was complicated. To illustrate how and what degree the body compositions contribute to BMD, a stepwise multivariate analysis

was performed. In male, LM strongly contributed to BMD in all models and positively affected on BMD. The LM often considered the major back muscles, provide support, and control movement of the spine. Many studies showed that LM was the strongest predictor of BMD [4], and the increase of muscle strength can help to maintain bone mass [10, 16]. Epidemiological studies showed that sarcopenia has evolved the key component regarding lean mass, which positively affect bone mass [17, 18]. Karasik et al. [16] reported that attracting genes, such as myostatin, a-actinin 3, proliferator-activated receptor gamma coactivator 1-alpha (PGC-1a), and myocyte enhancer factor 2 C (MEF-2C), are included in genome-wide association studies (GWAS) as being related to muscle loss and osteoporosis concurrently. A study by Terracciano et al. [19] revealed that osteoporosis is related to muscle atrophy, which correlated with the reduced level of protein kinase B (Akt), a component of the insulin-like growth factor (IGF)-I/phosphatidylinositol 3-kinase (PI3-K)/Akt pathway. In addition, the contribution of LM to BMD was found more remarkable in male than in female. Narendra et al. [20] showed that hypogonadism of male was a strong risk for osteoporosis. Hypogonadism leads to a reduction in restosterone which can decrease muscle mass and protein synthesis metabolism. A meta-analysis of placebo-controlled trials of testosterone treatment in men with androgen deficiency suggested a beneficial effect on lumbar spine BMD [3].

In female, SAT is a major source of aromatase in female [21], which synthesizes estrogens from androgenic precursors. Estrogens play a pivotal role in the maintenance of skeletal health, protecting against osteoporosis by reducing bone resorption and stimulating bone formation. SAT further exerts mechanical stress on bone and therefore acts positively on BMD [22]. Inflammatory factors secreted by VAT [23] could increase bone resorption by stimulating osteoclast activity [24]. In contrast, leptin, hormone, which produced by SAT, might increase bone mass by stimulating osteoblast activity [25]. This confirmed the hypothesis that the different distributions of abdominal adipose tissue may have a different influence on BMD. FM and F/L negatively affected on BMD. The study of Inhwan Lee [26] supported the hypothesis that higher fat mass may be an independent risk factor for osteoporosis and for osteoporotic fractures, at least in female. Both osteoblasts and adipocytes originate from a common progenitor and bone marrow skeletal stem cells MSC [27], and their differentiation is regulated through the PPAR-γ (peroxisome proliferators activated receptor-gamma) pathway. Activation of PPAR-γ drives the differentiation of MSC toward adipocytes over osteoblasts [28]. Furthermore, with increasing obesity, the fat mass acts as an inflammatory depot to release proinflammatory cytokines, such as tumor necrosis factor (TNF)-a, interleukin (IL)-1, and IL-6, which deteriorate bone cells and bone structure. Although DXA is reliable in determining abdominal obesity, it is unable to distinguish different types of adipose tissues and muscles. Our study utilized QCT to obtain abdominal body composition, which enabled us to evaluate the effect of different adipose tissue depots and skeletal muscle on BMD. LM positive contributed to BMD, especially in male. SAT was an important influence on BMD in female. These have not been reported before.

The present study had some limitations. First, the measurement parameters of BMD and body compositions were not compared with DXA measurement. Secondly, the sample size of the study was not large enough, especially in male. All data were limited in Chinese populations. Thirdly, the study was limited to abdominal adipose tissue measurement at the L3 level which could not reflect the whole adipose distribution.

In summary, both BMD and body compositions displayed different characteristics in male and female with age. The contribution of body compositions to BMD was also different in both genders. In male, LM closely associated with BMD and positively affected on BMD. In female, BMD was closely correlated with adipose and fat distribution. SAT was the most important influence factor on BMD with a positive correlation; however, FM and F/L negatively affected on BMD.

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Compliance with ethical standards

The studies have been approved by the appropriate institutional and national research ethics committee and have been performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. Ethics committee of our institution approved the study, and informed consent was obtained from all individual participants included in the study.

Conflicts of interest None.

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