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Fat mass in postmenopausal women with osteoporosis is associated with cognitive function

Dongxue Zhang[1,3], Zijing Zhu[1,3], Lu Xue[1], Yifeng Zheng[1], Xiongfeng Li[1], Miyang Xu[2], Xinfang Xie[1,4]✉ & Yongli Wang[1,4]✉

Postmenopausal women undergo significant changes in endogenous hormones, which lead to reduced bone mineral density (BMD) and alterations in body composition. However, the relationship between body composition and cognitive function in this demographic has not yet been explored. This study aims to examine this relationship in postmenopausal women with osteoporosis.This survey will involve 120 postmenopausal women with osteoporosis. Dual-energy X-ray absorptiometry (DXA) will be used to assess L1-L4 BMD, fat mass (FM), trunk fat mass (TFM), fat-free mass (FFM), and appendicular skeletal muscle mass (ASMM). The relationship between body composition and cognitive function will be analyzed using t-tests and multiple linear regression.Our findings suggest that in postmenopausal women with osteoporosis, cognitive function (MMSE score) is positively correlated with body composition indicators such as FM and BMD, and positively correlated with educational level, but negatively correlated with age. FM plays a significant role in influencing cognitive function and is a crucial indicator of body composition in postmenopausal women with osteoporosis.

Keywords Body composition, postmenopausal osteoporosis, cognition function, fat mass, fat-free mass

Osteoporosis (OP) is a systemic skeletal disease characterized by decreased bone density and deterioration in bone structure, leading to reduced bone strength, increased bone fragility, and a higher risk of fractures[1,2]. In China, the incidence rate of osteoporosis among those aged 50 and above is 19.2%, with a prevalence rate of 6.0% in males and 32.1% in females[3]. Postmenopausal osteoporosis (PMOP) is the most prevalent type of primary osteoporosis. Following menopause, estrogen levels drop sharply, leading to a higher production of osteoclasts relative to osteoblasts. This imbalance accelerates bone loss and disrupts the metabolic balance of bone, culminating in osteoporosis[4,5]. Concurrently, the postmenopausal period marks a critical phase in female aging. The decline in estrogen not only affects bone health but also alters body composition, leading to increased fat accumulation, muscle loss, and reduced muscle strength. In severe cases, this can progress to sarcopenia[6]. These changes in bone structure and muscle function can cause symptoms like multi-joint pain, muscle loss, skeletal deformities, and fractures, which significantly burden postmenopausal women both physically and mentally, impacting their quality of life and leading to substantial socio-economic losses[1,3].

Increasing evidence suggests a correlation between OP and cognitive impairment (CI)[7,8]. Cognitive impairment, a precursor to dementia, is marked by mild yet significant deficits in memory and/or other cognitive functions, impacting daily life activities[9]. It has emerged as a critical public health issue among the elderly. Often, low bone density and cognitive impairment occur concurrently[10]. For instance, Ebrahimpur et al. reported that women with low spinal bone density have a 1.83-fold increased risk of cognitive impairment (95% CI: 1.13–2.96)[11]. Additionally, changes in body composition may influence cognitive functions[12], yet the relationship and underlying mechanisms between these factors remain unclear, particularly among postmenopausal women with osteoporosis. This study aims to explore this relationship.

Materials and methods

Study population

This study was conducted on 120 postmenopausal women with osteoporosis at Huzhou Central Hospital from November 2023 to March 2024, with approval from the Medical Ethics Committee of Huzhou Central Hospital (No. 202303041-01). Each patient in this experiment provided written informed consent.

[1]Huzhou Central Hospital, Affiliated Central Hospital of Huzhou University, Huzhou, China. [2]Huzhou Central Hospital, Fifth School of Clinical Medicine of Zhejiang Chinese Medical University, Huzhou, China. [3]Dongxue Zhang and Zijing Zhu contributed equally. [4]Yongli Wang and Xinfang Xie contributed equally. ✉email: xxf7281517@163.com; wyl1944@hzhospital.com

Inclusion criteria included postmenopausal women with a T-score of axial bone (lumbar spine) density ≤ -2.5 or a T-score between − 1.0 and − 2.5 with a brittle fracture in the proximal humerus, pelvis, or distal forearm[13].

Exclusion criteria encompassed non-natural menopause, patients who had undergone lumbar spine surgery, those with severe physical and mental illnesses (such as speech or hearing impairments, mental disorders, primary or metastatic malignant tumors) that could interfere with testing, and cases of secondary osteoporosis.

Height and weight testing methods

Height and weight were measured using the Giant Sky Ultrasonic Height and Weight Measuring Instrument (model: JT-918 C). Body mass index (BMI) was calculated using the standard formula: BMI = weight (kg) / height^2 (m^2.

Body composition testing

Dual-energy X-ray absorptiometry (DXA) is the gold standard for diagnosing osteoporosis and also serves as a non-invasive method for assessing fat, muscle, and bone density, providing more accurate results compared to bioelectrical impedance analysis for skeletal muscle measurement[14,15]. During the assessment, patients wore only underwear and removed all metal accessories. The DXA machine (GE Lunar Prodigy Advance) utilized two X-ray beams at different energy levels to measure fat mass (FM), trunk fat mass (TFM), fat-free mass (FFM), appendicular skeletal muscle mass (ASMM), and L1-L4 bone mineral density (BMD)[16]. The machine was calibrated every morning and at the end of each day for all measurements. Compared to other methods such as total body potassium (TBK), magnetic resonance imaging (MRI) or computer tomography (CT) imaging, DXA offers accuracy, simplicity, and practicality, with low radiation exposure and minimal risk. Apart from pregnancy, there are no contraindications for DXA use in clinical practice[17].

Demographics and covariates

Data were collected through interviews conducted by professional researchers. The questionnaire covered age, educational level, age at menarche, age at menopause, duration of menopause, number of pregnancies, number of births, proportion of meat consumption in the diet, and cognitive function. Cognitive function was assessed using the Mini Mental State Examination (MMSE), an 11-question test that can be completed in 5–10 minutes[18]. A total MMSE score of 30 points indicates higher cognitive function, with a score ≥ 24 suggesting normal cognition[19]. The Chinese version of the MMSE, widely used in both clinical settings and research, has been validated for the Chinese population[20].

Statistical analysis

We described participant characteristics using percentages for categorical variables and means with standard deviations for continuous variables. We grouped and characterized patients with cognitive impairment and severe osteoporosis, using frequencies and percentages for categorical variables, and compared them using the chi-square test. Continuous variables were represented as mean ± standard deviation and compared using the t-test or Mann-Whitney U test, depending on normality as assessed by the Shapiro-Wilk test. We identified factors related to cognitive function scores, including L1-L4 bone density and total fat mass.

Factors associated with cognitive function and having p-values less than 0.05 were included in a multiple linear regression analysis. We determined the key factors affecting cognitive function scores through stepwise regression based on the minimum Akaike Information Criterion (AIC). The results are presented as regression coefficients with 95% confidence intervals (CI).

We stratified participants for cognitive impairment and examined the relationships between height, weight and fat-free mass (FFM) with osteoporosis. Similarly, we stratified participants with severe osteoporosis to compare the relationships between total fat mass (FM) and other related variables with cognitive function. A p-value less than 0.05 was considered statistically significant. All analyses were conducted using R software (version 4.3.1).

Results

Population characteristics

This study included 120 postmenopausal women with osteoporosis, summarized in Table 1. The average age was 66.84 ± 8.83 years, and the average duration of menopause was 17.47 ± 9.71 years. About 49% of participants had an education level of junior high school or lower. The average BMI was 21.61 ± 2.77 kg/m2, average FM was 18.08 ± 4.79 kg, average TFM was 10.09 ± 3.29 kg, average FFM was 34.63 ± 4.24 kg, and average ASMM was 13.98 ± 1.97 kg. The mean MMSE score was 23.62 ± 4.51 points, and the average L1-L4 BMD was 0.8 ± 0.12 kg/cm2. All patients had a T-score of ≤ -1.

Cognitive function related factors

Participants were divided into two groups based on MMSE scores: a non-cognitive impairment group (MMSE score ≥ 24) and a cognitive impairment group[19]. Table 2 shows the results. There were 51 individuals in the cognitive impairment group and 69 in the non-cognitive impairment group, with a cognitive impairment incidence rate of 42.5%. The average age of the non-cognitive impairment group (63.75 ± 8.24 years) was significantly lower than that of the cognitive impairment group (71.02 ± 7.89 years) ($p < 0.05$). The non-cognitive impairment group also showed younger ages at menarche and fewer numbers of births compared to the cognitive impairment group ($p < 0.05$). The average duration of menopause was shorter in the non-cognitive impairment group (14.65 ± 9.14 years) compared to the cognitive impairment group (21.27 ± 9.22 years) ($p < 0.05$). The non-cognitive impairment group had better nutritional management and higher educational levels than the cognitive impairment group ($p < 0.05$).

Variables	*n*=120
Age	66.84± 8.83
Educational level	
illiteracy	29(24)
primary school	30(25)
Junior high school and above	61(51)
duration of menopause	17.47± 9.71
Age of menarche	
12	5(4)
13	14(12)
14	28(23)
15	21(18)
16	18(15)
17	15(13)
18	13(11)
19	3(3)
20	3(3)
Age of menopause	49.38±3.23
Pregnancy frequency	
1	7(6)
2	34(28)
3	44(37)
4	23(19)
5	6(5)
6	4(3)
7	1(0)
8	1(0)
Production frequency	
1	52(43)
2	44(37)
3	17(14)
4	5(4)
6	2(2)
The proportion of meat in the diet	
30%below	54 (45)
30%-50%	52 (43)
50% above	14 (12)
MMSE score	23.62±4.51
Body composition	
L1-L4BMD(kg/m²)	0.80±0.12
Height(m)	1.56±0.06
Weight(kg)	52.71±7.97
BMI (kg/m2)	21.61±2.77
Fat Mass(kg)	18.08±4.79
Trunk Fat Mass(kg)	10.09±3.29
Fat-Free Mass(kg)	34.63±4.24
Appendicular Skeletal muscle Mass(kg)	13.98±1.97

Table 1. General characteristics and body composition of study participants (*n*=120).

The average L1-L4 BMD in the non-cognitive impairment group (0.83 ± 0.1 kg/cm2) was higher than in the cognitive impairment group (0.76 ± 0.14 kg/cm2) ($p < 0.05$). The average height of the non-cognitive impairment group (1.57 ± 0.06 m) was also higher than that of the cognitive impairment group (1.54 ± 0.05 m) ($p < 0.05$). The average FM in the non-cognitive impairment group (18.96 ± 3.99 kg) was higher than in the cognitive impairment group (16.89 ± 5.53 kg) ($p < 0.05$). Similarly, the average TFM was higher in the non-cognitive impairment group (10.74 ± 2.79 kg) compared to the cognitive impairment group (9.21 ± 3.71 kg) ($p < 0.05$).

However, the differences in average FFM (34.99 ± 4.25 kg vs. 34.13 ± 4.22 kg) and ASMM (14.19 ± 1.93 kg vs. 13.69 ± 2 kg) between the groups were not statistically significant ($p > 0.05$).

Cognitive impairment				
Variables	**Total ($n=120$)**	**Yes($n=51$)**	**No($n=69$)**	**p Value**
Age	66.84 ± 8.83	71.02 ± 7.89	63.75 ± 8.24	< 0.001
Educational level				< 0.001
illiteracy	29 (24)	25 (49)	4 (6)	
primary school	30 (25)	15 (29)	15 (22)	
Junior high school and above	61 (51)	11 (22)	50 (72)	
duration of menopause	17.47 ± 9.71	21.27 ± 9.22	14.65 ± 9.14	< 0.001
Age of menarche				0.047
12	5 (4)	0 (0)	5 (7)	
13	14 (12)	3 (6)	11 (16)	
14	28 (23)	9 (18)	19 (28)	
15	21 (18)	8 (16)	13 (19)	
16	18 (15)	9 (18)	9 (13)	
17	15 (12)	10 (20)	5 (7)	
18	13 (11)	8 (16)	5 (7)	
19	3 (2)	2 (4)	1 (1)	
20	3 (2)	2 (4)	1 (1)	
Age of menopause	50 (48, 51.25)	50 (48, 52)	49 (48, 51)	0.076
Pregnancy frequency				0.119
1	7 (6)	2 (4)	5 (7)	
2	34 (28)	12 (24)	22 (32)	
3	44 (37)	22 (43)	22 (32)	
4	23 (19)	7 (14)	16 (23)	
5	6 (5)	5 (10)	1 (1)	
6	4 (3)	1 (2)	3 (4)	
7	1 (1)	1 (2)	0 (0)	
8	1 (1)	1 (2)	0 (0)	
Production frequency				< 0.001
1	52 (43)	11 (22)	41 (59)	
2	44 (37)	26 (51)	18 (26)	
3	17 (14)	9 (18)	8 (12)	
4	5 (4)	3 (6)	2 (3)	
6	2 (2)	2 (4)	0 (0)	
The proportion of meat in the diet				0.031
30%below	54 (45)	30 (59)	24 (35)	
30%-50%	52 (43)	16 (31)	36 (52)	
50% above	14 (12)	5 (10)	9 (13)	
Body composition				
L1-L4BMD(kg/m²)	0.8 ± 0.12	0.76 ± 0.14	0.83 ± 0.1	0.001
Height(m)	1.56 ± 0.06	1.54 ± 0.05	1.57 ± 0.06	0.003
Weight(kg)	52.71 ± 7.97	51.03 ± 8.7	53.96 ± 7.21	0.046
BMI (kg/m2)	21.61 ± 2.77	21.38 ± 3.09	21.78 ± 2.52	0.442
Fat Mass(kg)	18.08 ± 4.79	16.89 ± 5.53	18.96 ± 3.99	0.018
Trunk Fat Mass(kg)	10.09 ± 3.29	9.21 ± 3.71	10.74 ± 2.79	0.011
Fat-Free Mass(kg)	34.63 ± 4.24	34.13 ± 4.22	34.99 ± 4.25	0.275
Appendicular Skeletal muscle Mass(kg)	13.98 ± 1.97	13.69 ± 2	14.19 ± 1.93	0.169

Table 2. Cognitive function related factors.

The relationship between cognitive function and age, educational level, L1-L4BMD, and FM

Multivariate linear regression analyses revealed significant relationships between cognitive function scores and several variables. Age was negatively associated with cognitive function (β = -0.14, 95% CI [-0.22, -0.07], $p < 0.001$). Educational level showed a positive correlation with cognitive function (β = 2.76, 95% CI [1.13, 4.39], $p < 0.001$). L1-L4 BMD was also positively correlated (β = 6.12, 95% CI [0.89, 11.34], $p = 0.022$), as was total FM (β = 0.20, 95% CI [0.08, 0.33], $p = 0.002$). These findings are summarized in Table 3.

Variables	β (95% CI) *	*p* Value **
Age	-0.14(-0.22;-0.07)	< 0.001
Educational level	—	—
illiteracy		
primary school	2.76(1.13;4.39)	0.001
Junior high school and above	4.79(3.28;6.30)	<0.001
L1-L4BMD(kg/m^2)	6.12(0.89;11.34)	0.022
Fat Mass(kg)	0.20(0.08;0.33)	0.002

Table 3. The relationship between cognitive function and age, educational level, L1-L4BMD, and FM. * β (95% IC): linear regression coefficient β (95% confidence interval). ** p value: significant difference if p-value < 0.05 (highlighted in bold).

Factors related to bone density

Participants were categorized into two groups based on a T-score of ≤ -3: those at high risk of fracture were divided into severe osteoporosis group(T1) and osteoporosis group(T2)[13], as shown in Table 4. The T1 group included 68 individuals, while the T2 group had 52 individuals. The average age in the T1 group was 68.88 ± 8.85 years, which was significantly higher than the average age of 64.17 ± 8.14 years in the T2 group ($p < 0.05$). The average duration of menopause was longer in the T1 group (19.68 ± 9.73 years) compared to the T2 group (14.58 ± 8.98 years) ($p < 0.05$). The average age at menarche was higher in the T1 group than in the T2 group ($p < 0.05$). Conversely, the education level was lower in the T1 group compared to the T2 group ($p < 0.05$).

In terms of body measurements, the average height in the T1 group was 1.55 ± 0.06 m, lower than the 1.58 ± 0.04 m in the T2 group ($p < 0.05$). The average weight in the T1 group was 50.65 ± 7.45 kg, lower than the 55.4 ± 7.9 kg in the T2 group ($p < 0.05$). The average BMI in the T1 group was 21.15 ± 2.57 kg/m2, lower than the 22.2 ± 2.94 kg/m2 in the T2 group ($p < 0.05$). The average total FM was 17.27 ± 4.63 kg in the T1 group, lower than the 19.14 ± 4.84 kg in the T2 group ($p < 0.05$). The average TFM was 9.41 ± 3.18 kg in the T1 group, lower than the 10.98 ± 3.23 kg in the T2 group ($p < 0.05$). The average FFM was 33.38 ± 3.89 kg in the T1 group, lower than the 36.26 ± 4.16 kg in the T2 group ($p < 0.05$). The average ASMM was 13.51 ± 1.94 kg in the T1 group, lower than the 14.59 ± 1.84 kg in the T2 group ($p < 0.05$).

Severity stratification of osteoporosis, relationship between body composition and cognitive function

In the severe osteoporosis group, several body composition measures including height, weight, total fat mass, and trunk fat mass were significantly lower in the cognitive impairment subgroup compared to those without cognitive impairment ($p < 0.05$), as shown in Table 5.

Stratification of cognitive impairment, relationship between body composition and severity of osteoporosis

Within the cognitive impairment group, those with severe osteoporosis had lower values for height, weight, and fat-free mass compared to those with osteoporosis ($p < 0.05$).Besides, in the non-cognitive impairment group, fat-free mass was lower in the severe osteoporosis subgroup compared to the osteoporosis group ($p < 0.05$), as depicted in Fig. 1.

Discussion

We assessed the body composition and MMSE scores of 120 postmenopausal women diagnosed with osteoporosis. Our results indicated a positive correlation between cognitive function (measured by MMSE scores) and body composition indicators such as FM and BMD. Additionally, cognitive function positively correlated with education level and negatively with age among these women. Those in the cognitive impairment group were characterized by a later age of onset, more frequent childbirth, poor nutritional management, lower weight, and shorter stature. Women with severe osteoporosis after menopause exhibited lower FM, TFM, FFM, and ASMM. Factors such as older age, later menarche, lower education level and lower BMI were associated with severe osteoporosis.

There is a correlation between osteoporosis and cognitive function[21].Research by Jiang et al. has demonstrated a communication mechanism between the bone and brain. Extracellular vesicles derived from healthy bone cells (OCY-EVs) can transfer to the brain under both physiological and pathological conditions, potentially ameliorating cognitive impairment in Alzheimer's disease[22]. This supports the notion that healthy bones, indicative of good bone density, are linked to higher cognitive functions, aligning with our findings.

Endogenous estradiol is known for its neuroprotective effects in models of oxidative stress, excitatory neurotoxicity, ischemia, and apoptosis, and it is associated with a reduced risk of cognitive impairment[23]. Our study corroborates that postmenopausal women with osteoporosis who do not have cognitive impairment tend to have experienced earlier menarche, suggesting that early menarche may confer benefits from the neuroprotective effects of estrogen, leading to higher cognitive functioning. As postmenopausal women age and estrogen levels decline sharply, changes in body composition (bones, muscles, and fat) occur alongside a decline in cognitive function[5,24,25]. FM, the main source of endogenous estrogen in postmenopausal women, shows a positive correlation with cognitive function in the Asian population[26,27]. As a component of body weight, FM

osteoporosis				
Variables	**Total (*n* = 120)**	**T1(*n* = 68)**	**T2(*n* = 52)**	**p Value**
Age	66.84 ± 8.83	68.88 ± 8.85	64.17 ± 8.14	0.003
Educational level				0.02
illiteracy	29 (24)	17 (25)	12 (23)	
primary school	30 (25)	23 (34)	7 (13)	
Junior high school and above	61 (51)	28 (41)	33 (63)	
duration of menopause	17.47 ± 9.71	19.68 ± 9.73	14.58 ± 8.98	0.004
Age of menarche				0.03
12	5 (4)	4 (6)	1 (2)	
13	14 (12)	7 (10)	7 (13)	
14	28 (23)	12 (18)	16 (31)	
15	21 (18)	7 (10)	14 (27)	
16	18 (15)	11 (16)	7 (13)	
17	15 (12)	12 (18)	3 (6)	
18	13 (11)	11 (16)	2 (4)	
19	3 (2)	2 (3)	1 (2)	
20	3 (2)	2 (3)	1 (2)	
Age of menopause	50 (48, 51.25)	49 (48, 51)	50 (48, 52)	0.251
Pregnancy frequency				0.331
1	7 (6)	3 (4)	4 (8)	
2	34 (28)	15 (22)	19 (37)	
3	44 (37)	27 (40)	17 (33)	
4	23 (19)	14 (21)	9 (17)	
5	6 (5)	3 (4)	3 (6)	
6	4 (3)	4 (6)	0 (0)	
7	1 (1)	1 (1)	0 (0)	
8	1 (1)	1 (1)	0 (0)	
Production frequency				0.122
1	52 (43)	28 (41)	24 (46)	
2	44 (37)	26 (38)	18 (35)	
3	17 (14)	7 (10)	10 (19)	
4	5 (4)	5 (7)	0 (0)	
6	2 (2)	2 (3)	0 (0)	
The proportion of meat in the diet				0.829
30%below	54 (45)	30 (44)	24 (46)	
30%-50%	52 (43)	29 (43)	23 (44)	
50% above	14 (12)	9 (13)	5 (10)	
Body composition				
Height(m)	1.56 ± 0.06	1.55 ± 0.06	1.58 ± 0.04	0.001
Weight(kg)	52.71 ± 7.97	50.65 ± 7.45	55.4 ± 7.9	0.001
BMI (kg/m2)	21.61 ± 2.77	21.15 ± 2.57	22.2 ± 2.94	0.039
Fat Mass(kg)	18.08 ± 4.79	17.27 ± 4.63	19.14 ± 4.84	0.034
Trunk Fat Mass(kg)	10.09 ± 3.29	9.41 ± 3.18	10.98 ± 3.23	0.009
Fat-Free Mass(kg)	34.63 ± 4.24	33.38 ± 3.89	36.26 ± 4.16	< 0.001
Appendicular Skeletal muscle Mass(kg)	13.98 ± 1.97	13.51 ± 1.94	14.59 ± 1.84	0.003

Table 4. Factors related to bone density. Abbreviations: T1,Severe osteoporosis; T2,osteoporosis.

influences the expression and release of sex hormones and molecules such as leptin, insulin, and adiponectin in adipose tissue. This leads to decreased bone turnover and resorption, an upregulation of osteoblast activity, and enhanced bone formation[28]. These findings are consistent with our observation that higher FM is associated with better cognitive function and higher BMD in postmenopausal women with osteoporosis. Furthermore, fat is also linked to nutritional intake[29]. Studies have indicated that women are more susceptible to malnutrition, particularly deficits in energy and protein, which are crucial factors leading to loss of physical function[30]. Nutrition significantly impacts cognitive function in postmenopausal women with osteoporosis. In our study, those who derived 30–50% of their diet from meat exhibited better cognitive function. A nutrient-rich diet is believed to be beneficial for overall health and brain aging, potentially reducing the incidence of dementia and

	osteoporosis $n=52$ (43)		p value	Severe osteoporosis $n=68$ (57)		p value
	non Cognitive impairment $n=35$ (67)	Cognitive impairment $n=17$ (33)		non Cognitive impairment $n=34$ (50)	Cognitive impairment $n=34$ (50)	
Height(m)	1.58 ± 0.05	1.57 ± 0.04	0.472	1.56 ± 0.06	1.53 ± 0.05	0.013
Weight(kg)	55.57 ± 7.61	55.04 ± 8.7	0.822	52.29 ± 6.46	49.02 ± 8.09	0.07
BMI (kg/m2)	22.18 ± 2.72	22.26 ± 3.43	0.931	21.36 ± 2.26	20.95 ± 2.86	0.505
Fat Mass(kg)	19.25 ± 4.15	18.92 ± 6.16	0.821	18.19 (16.39, 20.63)	15.58 (13.39, 17.37)	0.002
Trunk Fat Mass(kg)	11.08 ± 2.95	10.76 ± 3.84	0.743	10.39 ± 2.6	8.43 ± 3.44	0.01
Fat-Free Mass(kg)	36.32 ± 4.34	36.13 ± 3.87	0.873	33.62 ± 3.73	33.14 ± 4.09	0.613
Appendicular Skeletal muscle Mass(kg)	14.61 ± 1.94	14.54 ± 1.67	0.896	13.76 ± 1.85	13.27 ± 2.03	0.3

Table 5. Severity stratification of osteoporosis, relationship between body composition and cognitive function. a The relationship between fat free mass, cognitive function, and severity of osteoporosis. b The relationship between height, cognitive function, and severity of osteoporosis. c The relationship between weight, cognitive function, and severity of osteoporosis. Abbreviations: T1,Severe osteoporosis; T2,osteoporosis; CI, Cognitive impairment.

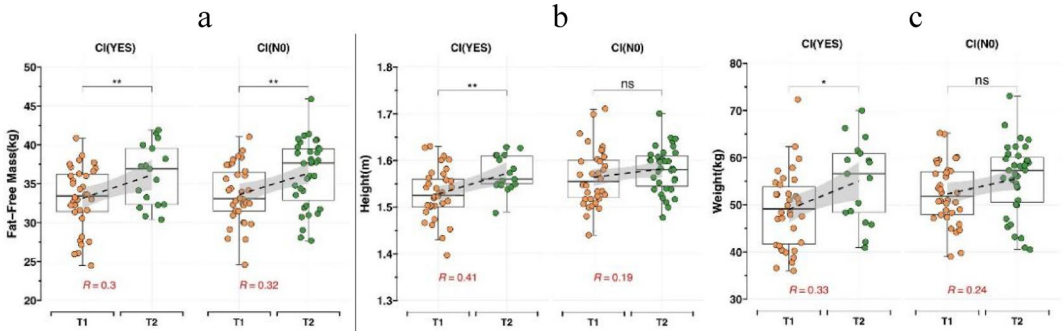

Fig. 1. Stratification of cognitive impairment, relationship between body composition and severity of osteoporosis. **a** The relationship between fat free mass, cognitive function, and severity of osteoporosis**b** The relationship between height, cognitive function, and severity of osteoporosis**c** The relationship between weight, cognitive function, and severity of osteoporosisAbbreviations:T1,Severe osteoporosis； T2,osteoporosis;CI, Cognitive impairment

maintaining brain health[31]. Thus, these factors may explain why higher FM is observed in postmenopausal women with osteoporosis who have better cognitive function.

Muscle wasting is a common factor influencing both osteoporosis and cognitive impairment[32]. In our study, the group of postmenopausal women with osteoporosis who exhibited cognitive impairment had significantly lower fat-free mass (FFM) and appendicular skeletal muscle mass (ASMM), although no differences were observed between groups. This outcome might be attributable to the fact that the participants were more engaged in physical labor, potentially leading to an increase in muscle mass. Cross-sectional studies have demonstrated that women with sarcopenia are five times more likely to develop cognitive impairment than those without sarcopenia[33]. Within the components of sarcopenia, which include muscle mass and muscle strength, muscle strength is positively correlated with cognitive function and may serve as a better predictive indicator of cognitive performance[34]. Moreover, our findings that FFM and ASMM are reduced in postmenopausal women with severe osteoporosis align with previous research[35]. Osteoporosis and sarcopenia may share common pathophysiological pathways, including hormonal imbalances, increased inflammatory cytokine activity, nutritional changes, and physical injuries[36]. Changes in endogenous hormones in postmenopausal women typically lead to decreases in muscle mass and bone density[37]. Estrogen helps maintain skeletal muscle contractility and prevents osteoporosis, while androgens and testosterone promote myoblast growth[27]. Additionally, many other tissue-specific factors released by muscles, such as insulin-like growth factor-1 (IGF-1), interleukin-6 (IL-6), and muscle growth inhibitor, can also regulate bone health[36]. Hu et al. found that individuals with sarcopenia are 1.43 times more likely to develop mild cognitive impairment than those without sarcopenia[38]. Sarcopenia is related to various brain phenotypes, including cortical thickness, brain volume, and white matter microstructure; the brain's sensory-motor system mediates the connection between muscle loss and cognitive features[39]. Therefore, sarcopenia is associated with decreased cognitive function and bone density in postmenopausal women with osteoporosis.

As age increases, cognitive function typically decreases, potentially leading to dementia in severe cases[40]. Research has shown a positive correlation between education level and cognitive function[41]. Similarly, our study

indicated that age and education level are strong predictors of cognitive function in postmenopausal women with osteoporosis. Childbirth increases the risk of cognitive decline and dementia by affecting neurodegenerative markers such as HVa, SPARE-AD volume, and SPARE-BA volume[42]. Compared to women who have not given birth, those who have given birth experience an approximate 22% decrease in estrogen levels and a shortened menstrual cycle, reflecting a decrease in cumulative estrogen exposure[43]. In our study, postmenopausal women with osteoporosis who displayed poor cognitive function had given birth more frequently, consistent with previous findings[42]. Additionally, women in our study with poorer cognitive function exhibited significantly lower height. Height, an indicator of health and nutrition primarily influenced by genetic factors, affects individual development and is positively correlated with physical health levels, potentially impacting the cognitive function of postmenopausal women with osteoporosis[44,45].

Our research focuses primarily on the objective measurements of body composition and cognition in postmenopausal women with osteoporosis, which is crucial for understanding this demographic. Body composition was measured using DXA, providing more accurate data than previous studies. However, our study's limitation is that it only includes postmenopausal women with osteoporosis from Huzhou, Zhejiang Province, China. Consequently, our conclusions cannot be generalized to the entire population. To better understand the relationship between body composition and cognitive function in postmenopausal women with osteoporosis in the future, it will be necessary to expand the sample size and include additional FM-related body composition indicators, which may provide a more detailed explanation of the role of fat in cognitive function in this group.

Conclusions

FM is a crucial factor affecting cognitive function in postmenopausal women with osteoporosis. Women with postmenopausal osteoporosis who have low FM tend to exhibit decreased cognitive function and are more susceptible to cognitive dysfunction. Furthermore, low FM is associated with severe osteoporosis in this group. Therefore, FM is an important indicator of body composition in postmenopausal women with osteoporosis. In summary, monitoring FM in postmenopausal women with osteoporosis is of great significance and should be considered as a key monitoring indicator for follow-up and intervention.

Data availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

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Author contributions

All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by DZ, ZZ, LX, YZ, XL, MX, XX, and YW. The first draft of the manuscript was written by DZ, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Declarations

Competing interests

The authors declare no competing interests.

Conflict of interest
The authors declare that there are no conflicts of interest.

Statement
This study had been approved by the Medical Ethics Committee of Huzhou Central Hospital (No. 202303041-01).And the study was performed in accordance with relevant regulations.And informed consent was obtained from all participants and/or their legal guardians.

Additional information
Correspondence and requests for materials should be addressed to X.X. or Y.W.

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