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Editorial Board Member of *World Journal of Orthopedics*, Mohamed Sukeik, FRCS (Ed), MD, Chief Physician, Surgeon, Department of Trauma and Orthopaedics, Dr. Sulaiman Al-Habib Hospital-Al Khobar, Al Khobar 34423, Saudi Arabia. msukeik@hotmail.com

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## Observational Study

## Relationships among body weight, lipids and bone mass in elderly individuals with fractures: A case-control study

Xiang-Xu Chen, Chu-Wei Tian, Li-Yong Bai, Ya-Kuan Zhao, Cheng Zhang, Liu Shi, Yuan-Wei Zhang, Wen-Jun Xie, Huan-Yi Zhu, Hui Chen, Yun-Feng Rui

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**Xiang-Xu Chen, Cheng Zhang, Liu Shi, Wen-Jun Xie, Hui Chen, Yun-Feng Rui,** Department of Orthopaedics, Trauma Center, Southeast University, Nanjing 210009, Jiangsu Province, China

**Chu-Wei Tian, Li-Yong Bai, Ya-Kuan Zhao, Yuan-Wei Zhang, Huan-Yi Zhu,** Department of Orthopaedics, Zhongda Hospital, School of Medicine, Southeast University, Nanjing 210009, Jiangsu Province, China

**Corresponding author:** Yun-Feng Rui, MD, PhD, Chief Doctor, Deputy Director, Professor, Surgeon, Department of Orthopaedics, Zhongda Hospital, School of Medicine, Southeast University, No. 87 Dingjiaqiao, Nanjing 210009, Jiangsu Province, China. [ruiyunfeng@126.com](mailto:ruiyunfeng@126.com)

## Abstract

### BACKGROUND

The prevalence of osteoporosis and low bone mass is steadily rising each year. Low body weight is commonly linked to diminished bone mass and serves as a robust predictor of osteoporosis. Nonetheless, the connection between body mass index (BMI), bone mineral density, and lipid profiles among the elderly remains elusive.

### AIM

To examine the association between BMI and bone mass, explore the correlation between lipid profiles and bone mass, and delve into the interplay between lipid metabolism and bone health.

### METHODS

The study included 520 patients aged  $\geq 65$  years (178 men and 342 women). Age, sex, weight, and height were recorded. Femoral neck bone mineral density and T scores were determined using a dual-energy X-ray absorptiometry scanner. Blood calcium (Ca), phosphorus (P), albumin (ALB), alkaline phosphatase (ALP), aspartate aminotransferase, alanine aminotransferase, triglyceride (TG), total cholesterol (TC), high-density lipoprotein (HDL) and low-density lipoprotein (LDL) levels were measured. Patients were classified by sex (male and female), age (65-79 years and  $\geq 80$  years), and T score (normal bone mineral density, osteopenia and osteoporosis).

### RESULTS

Age, sex, BMI, and ALP and TG levels were independent risk factors for osteoporosis. For the 65-79- and  $\geq 80$ -year-old groups, females presented lower T scores than males. Ca, P, ALB, ALP, TC, HDL and LDL levels were significantly different between men and women in the 65-79-year-old group. In addition, BMI and TG levels were significantly decreased in osteoporotic patients compared with patients with normal bone mass. TC levels declined in 65- to 79-year-old male and female osteoporosis patients. In the group of women aged  $\geq 80$  years, osteoporotic patients showed significantly increased ALP levels. Furthermore, we found positive correlations between BMI and TG levels in the male and female patient groups. However, we found no significant differences in ALB, Ca, P, HDL and LDL levels in osteoporotic patients compared to patients with normal bone mass.

## CONCLUSION

Osteoporotic patients showed significantly decreased BMI and TG levels compared with those with normal bone mass. BMI showed positive correlations with TG levels in male and female patients. These results indicate correlations between BMI and bone mass and between lipid profiles and bone mass.

**Key Words:** Osteoporosis; Weight loss; Elderly patients; Body mass index; Lipid profiles

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**Core Tip:** Older age, female gender, low body mass index (BMI), and low triglycerides (TG) were identified as overall independent factors for osteoporosis. Furthermore, low total cholesterol represented a gender-unspecific risk factor for osteoporosis in elderly patients aged 65-79 years, and high alkaline phosphatase represented a specific risk factor for osteoporosis in elderly male patients aged 80+ years. In addition, positive correlations were found between BMI and serum TG levels, suggesting an interaction between bone and fat metabolism that may have an impact on the development of osteoporosis and would provide a new strategy for the treatment of osteoporosis.

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## INTRODUCTION

The incidence of osteoporosis and low bone mass is progressively rising on an annual basis. Osteoporosis affects over 33% of individuals aged 50 years or older in China[1]. Osteoporosis is marked by diminished bone mineral density (BMD) and compromised bone microarchitecture, resulting in reduced bone mass and heightened bone fragility, thereby elevating the susceptibility to fractures[2]. Numerous factors contribute to osteoporosis, encompassing age, sex, lifestyle, and various medical conditions[3]. Alongside the T score, dual-energy X-ray absorptiometry (DXA) is deemed a pivotal and extensively employed technique for osteoporosis diagnosis[4]. Typically, osteoporosis is classified based on the T score, following the World Health Organization (WHO) guidelines: Normal bone density ( $\geq -1.0$ ), osteopenia ( $-1.0$  to  $-2.5$ ), and osteoporosis ( $\leq -2.5$ )[5,6].

Recently, numerous studies have examined osteoporosis risk factors, including body mass index (BMI), serum lipid profiles, serum calcium (Ca) and phosphorus (P), serum albumin (ALB), alkaline phosphatase (ALP), and serum alanine transaminase (ALT) and aspartate aminotransferase (AST)[7-11].

Previous research has reported a link between obesity and osteoporosis, suggesting that obesity might act as a protective factor against osteoporosis[12,13]. Obese individuals subject their bones to greater mechanical loads, which can be advantageous for bone mass[14,15]. Furthermore, weight loss detrimentally impacts musculoskeletal health[16], and it has been linked to bone loss and identified as a potent predictor of osteoporosis[17]. Elderly women who experienced weight loss demonstrated heightened bone loss in the hip region[18]. Another investigation noted a relationship between weight loss and hip-bone loss among elderly men and women[17]. These findings imply that elderly individuals with lower body weight face greater risks of both osteoporosis and fractures than their counterparts with higher body weight. Additionally, plasma lipid profiles have been demonstrated to undergo alterations in response to weight changes[19]. Assessing BMI provides a straightforward approach to categorizing an individual's weight status and is linked to the proportion of body fat[20].

Nevertheless, the relationship among BMI, bone mass, and lipid profiles remains unexplored in populations with osteoporosis and fragility fractures. Fragility fractures frequently occur in elderly patients with severe osteoporosis, exacerbating the prognosis[21]. The impact of weight gain on enhancing the lipid profile and subsequently mitigating the prevalence of osteoporosis and fragility fractures remains uncertain. This study aimed to examine the interaction between BMI and bone mass, explore the correlation between lipid profiles and bone mass, and further analyze the interrelationship between lipid metabolism and bone health in individuals experiencing fragility fractures.

## MATERIALS AND METHODS

### Study participants

This retrospective study was conducted at a singular orthopaedic trauma centre during the time span of January 2017 to December 2020. The study meticulously applied specific inclusion and exclusion criteria as delineated below:

**Inclusion criteria were as follows:** (1) Age exceeding 65 years at the moment of injury; (2) confirmed diagnosis of fractures in the hip, vertebral region, distal radius, or proximal humerus; and (3) hospitalization at our centre.

**Exclusion criteria were as follows:** (1) Patients afflicted with cancer, thyroid disorders, hypopituitarism, rheumatoid arthritis, chronic renal failure, or renal insufficiency; (2) patients undergoing lipid-lowering, synthetic thyroid, or hormone replacement therapies; or (3) presence of incomplete data.

Our study managed to acquire comprehensive clinical data suitable for analysis. Participants were categorized based on gender (male and female), age groups (65-79 years and  $\geq 80$  years), BMI ranges ( $< 18.5$ , 18.5-24,  $> 24$  kg/m<sup>2</sup>), and T scores [normal BMD ( $\geq -1.0$ ), osteopenia (-1.0 to -2.5), and osteoporosis ( $\leq -2.5$ )]. All laboratory data used in this study were obtained from blood samples collected during the initial admission.

### Data collection

Age, sex, height, and weight were recorded from patient documents. BMI was calculated using weight and height (kg/m<sup>2</sup>). Femoral neck BMD and T scores were determined using a DXA scanner (Hologic Discovery Wi with software version 13.2). According to the WHO classification, the T score was used to define the BMD categories. Serum samples were collected immediately after the patients were admitted, and serum Ca, P, ALB, AST, ALT, ALP, triglyceride (TG), total cholesterol (TC), high-density lipoprotein (HDL) and low-density lipoprotein (LDL) levels were analyzed.

### Statistical analysis

Data are presented as the mean  $\pm$  standard deviation (SD). IBM SPSS statistics software (version 26.0, SPSS Inc., Chicago, United States) and GraphPad Prism software (version 8.4.0, GraphPad Software, Boston, United States) were used to analyze the data. After analysing the normality using the Shapiro-Wilk test, data between two groups were evaluated by the *t* test and nonparametric test. For three groups, data were evaluated by one-way ANOVA. Multivariate analysis was performed by multiple linear regression. The Pearson correlation test was used to analyse the association between BMI and TG levels. <sup>a</sup>*P* < 0.05, <sup>b</sup>*P* < 0.01, <sup>c</sup>*P* < 0.001 and <sup>d</sup>*P* < 0.0001 indicated significant differences.

## RESULTS

In total, 520 patients aged  $\geq 65$  years were included in our study. A total of 178 male patients were enrolled, including 48 normal, 81 osteopenic and 49 osteoporotic patients. A total of 342 female patients were included in our study, including 37 normal, 103 osteopenic, and 202 osteoporotic patients (Table 1). Age, sex, BMI and ALP and TG concentrations were significantly different among the groups of normal, osteopenic and osteoporotic patients. Moreover, age, sex, BMI and ALP and TG concentrations were independent risk factors for osteoporosis (Table 1).

Patients were divided into two groups according to age (65-79 years and  $\geq 80$  years). To analyze sex differences, a total of 106 men and 188 women were included in the 65- to 79-year age group (Table 2). As shown in Table 2, there were significant differences in the T score and Ca, P, ALB, ALP, TC, HDL and LDL concentrations between male and female patients. However, male patients showed no difference in age, BMI, or AST, ALT and TG concentrations in comparison with female patients.

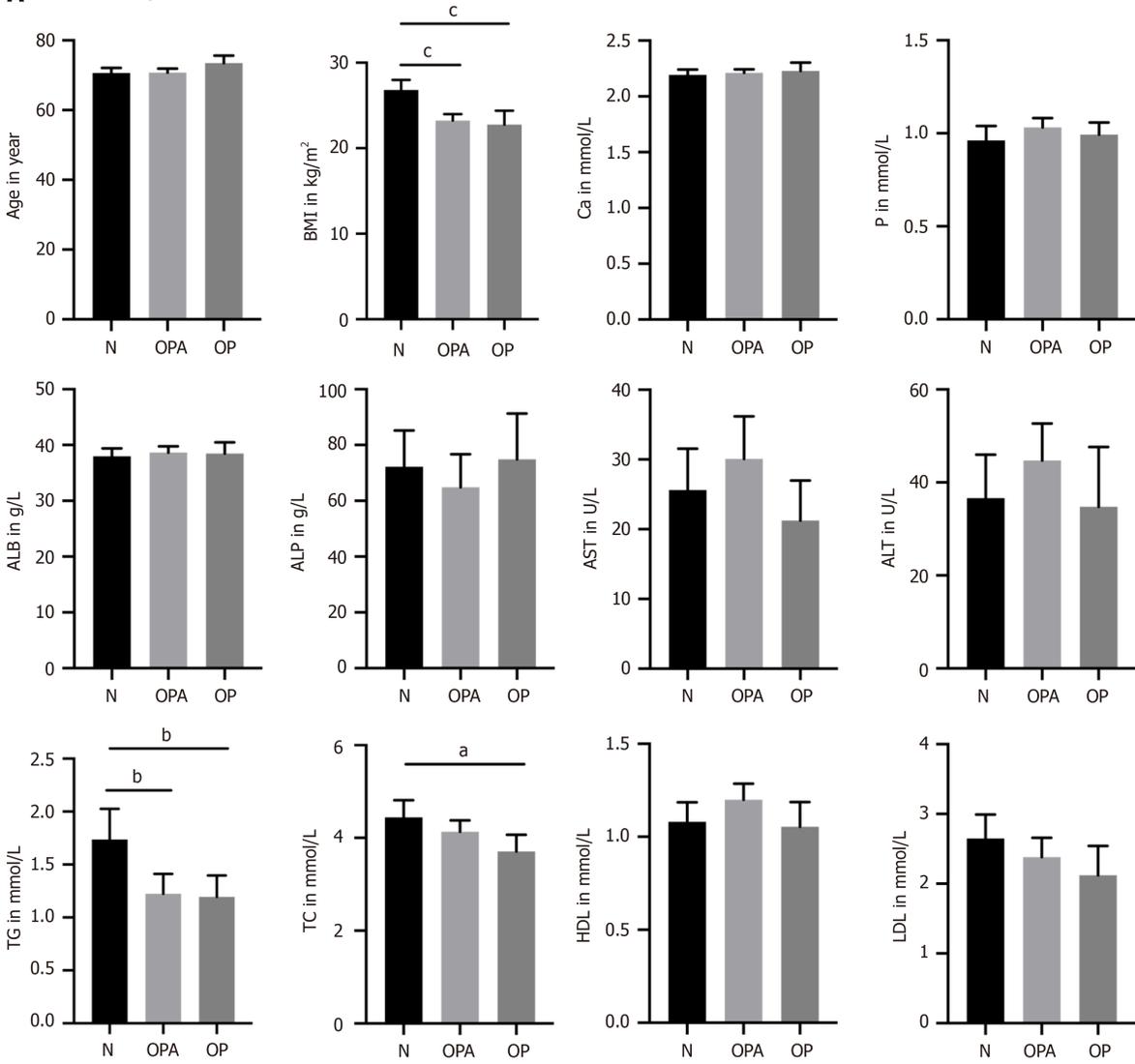
A total of 72 men and 154 women aged  $\geq 80$  years were examined in our study. The T score was significantly different in male patients compared to female patients. There were no significant differences in BMI or Ca, P, ALB, ALP, AST, ALT, TG, TC, HDL and LDL concentrations between male and female patients (Table 3).

In the group of 65- to 79-year-old male patients, BMI was lower in osteoporotic patients than in patients with normal bone mass. Furthermore, we found a positive correlation between BMI and T-value in the groups of male patients (Supplementary Figure 1). Moreover, TG and TC levels were also lower in patients with osteoporosis compared to those with normal bone mass. Osteoporotic patients showed no significant differences in Ca, P, ALB, ALP, AST, ALT, HDL and LDL levels compared to patients with normal bone mass. In men aged  $\geq 80$  years, BMI was significantly lower in osteoporotic patients than in patients with normal bone mass. We also observed decreased TG levels in osteoporotic patients compared to those in patients with normal bone mass. Ca, P, ALB, ALP, AST, ALT, TC, HDL and LDL levels were not significantly different between patients with and without osteoporosis (Figure 1).

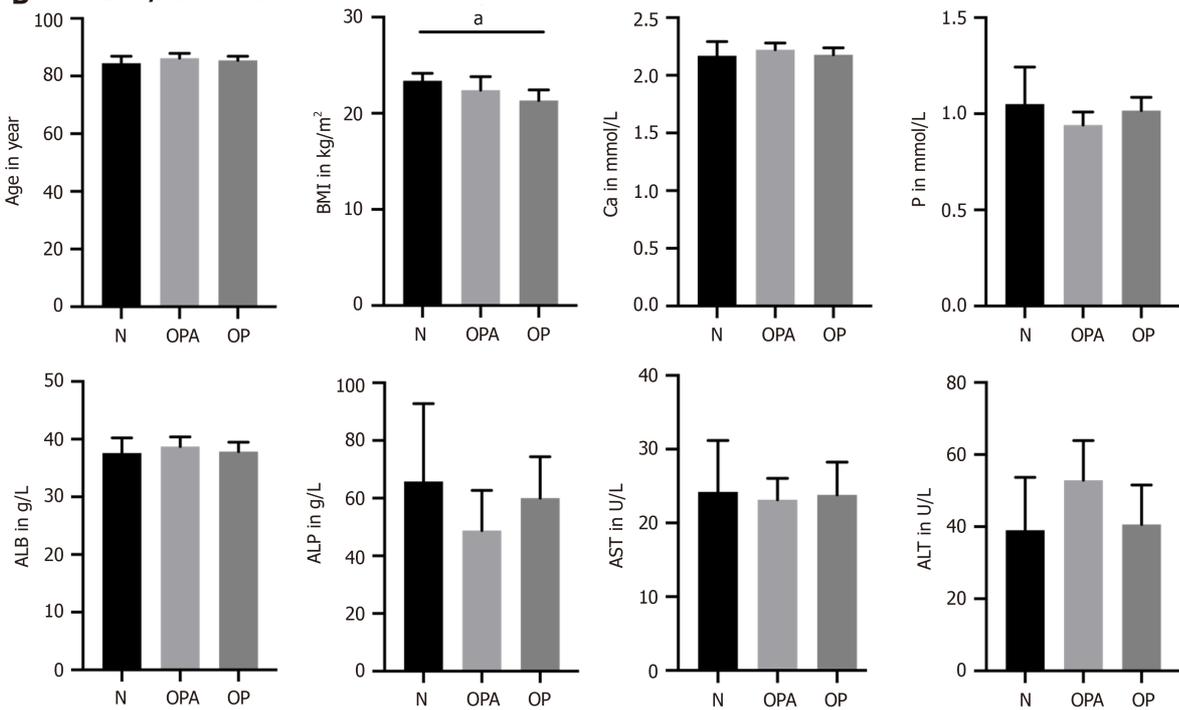
In the group of 65- to 79-year-old females, BMI and TG levels were significantly lower in osteoporotic patients than patients with normal bone mass. We also found a positive correlation between BMI and T-value in the groups of female patients (Supplementary Figure 1). Osteoporotic patients also showed no significant differences in Ca, P, ALB, ALP, AST, ALT, HDL and LDL levels compared to patients with normal bone mass. In the group of women aged  $\geq 80$  years, osteoporotic patients showed significantly decreased BMI and TG levels as well as increased ALP levels. We also did not find significant differences in the Ca, P, ALB, AST, ALT, TC, HDL and LDL levels in osteoporotic patients compared with patients with normal bone mass (Figure 2).

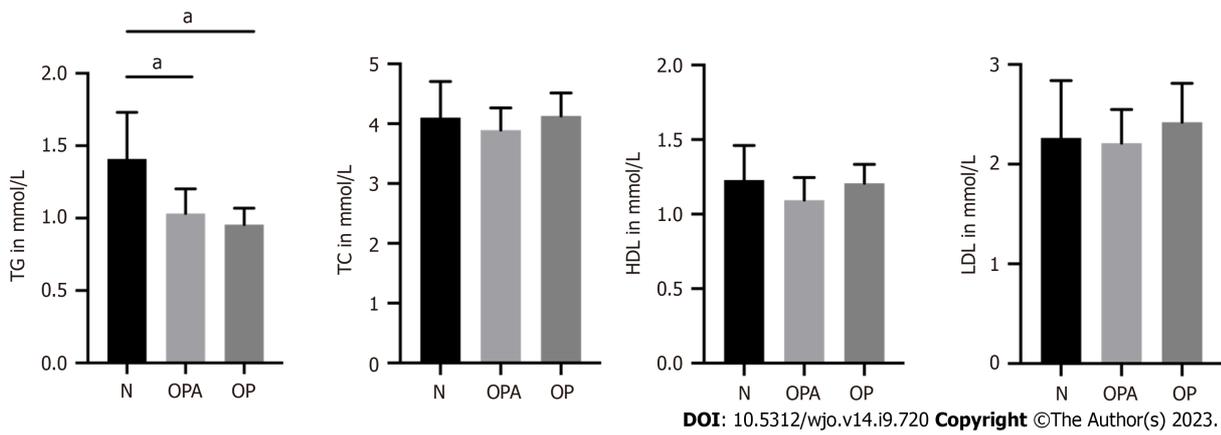
Furthermore, we found a positive correlation between BMI and TG levels in the groups of male patients aged 65-79 and  $\geq 80$  years. A positive correlation was also found between BMI and TG levels in the groups of 65-79- and  $\geq 80$ -year-old

**A** 65-79 years old male



**B** ≥ 80 years old male

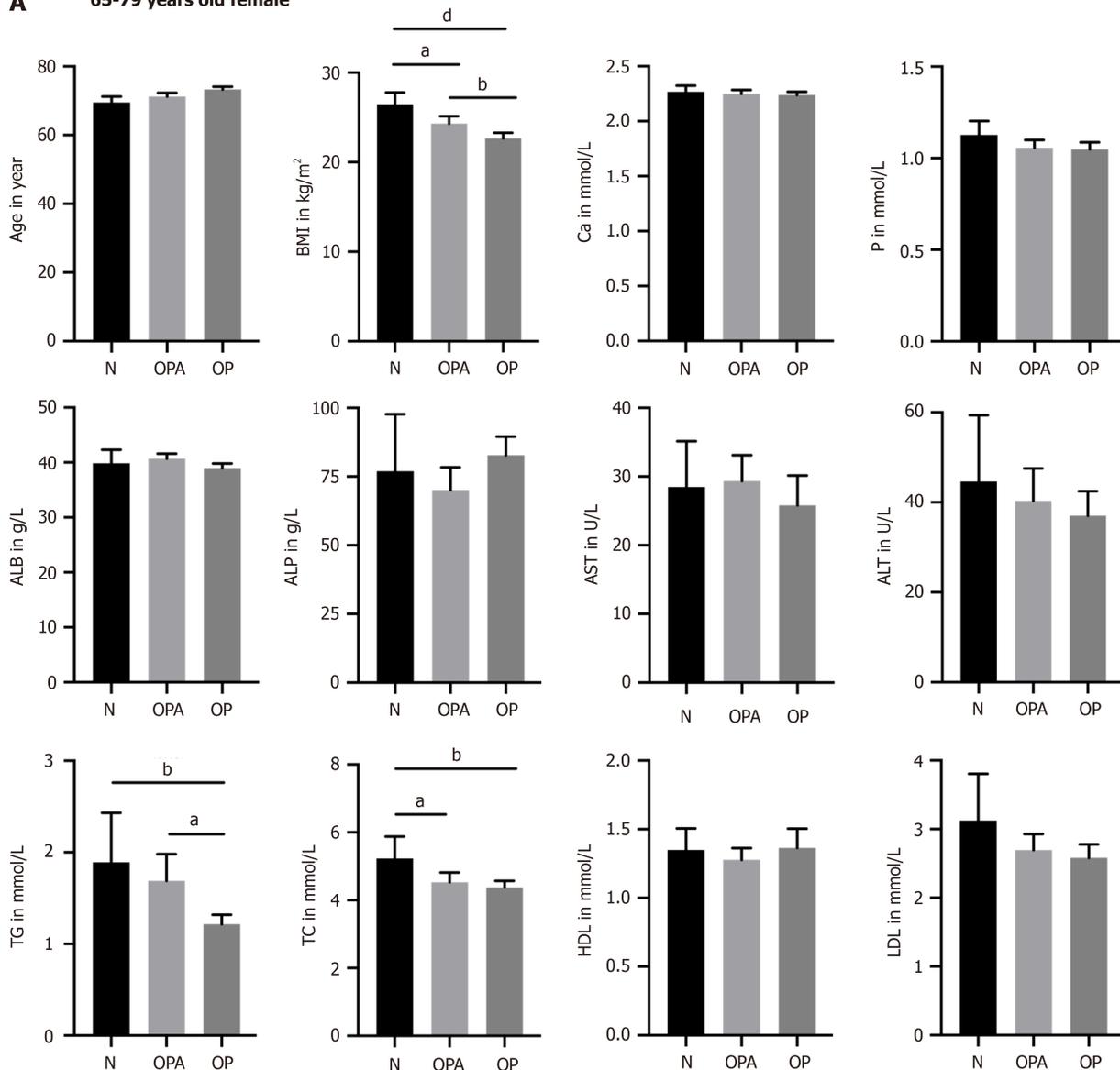


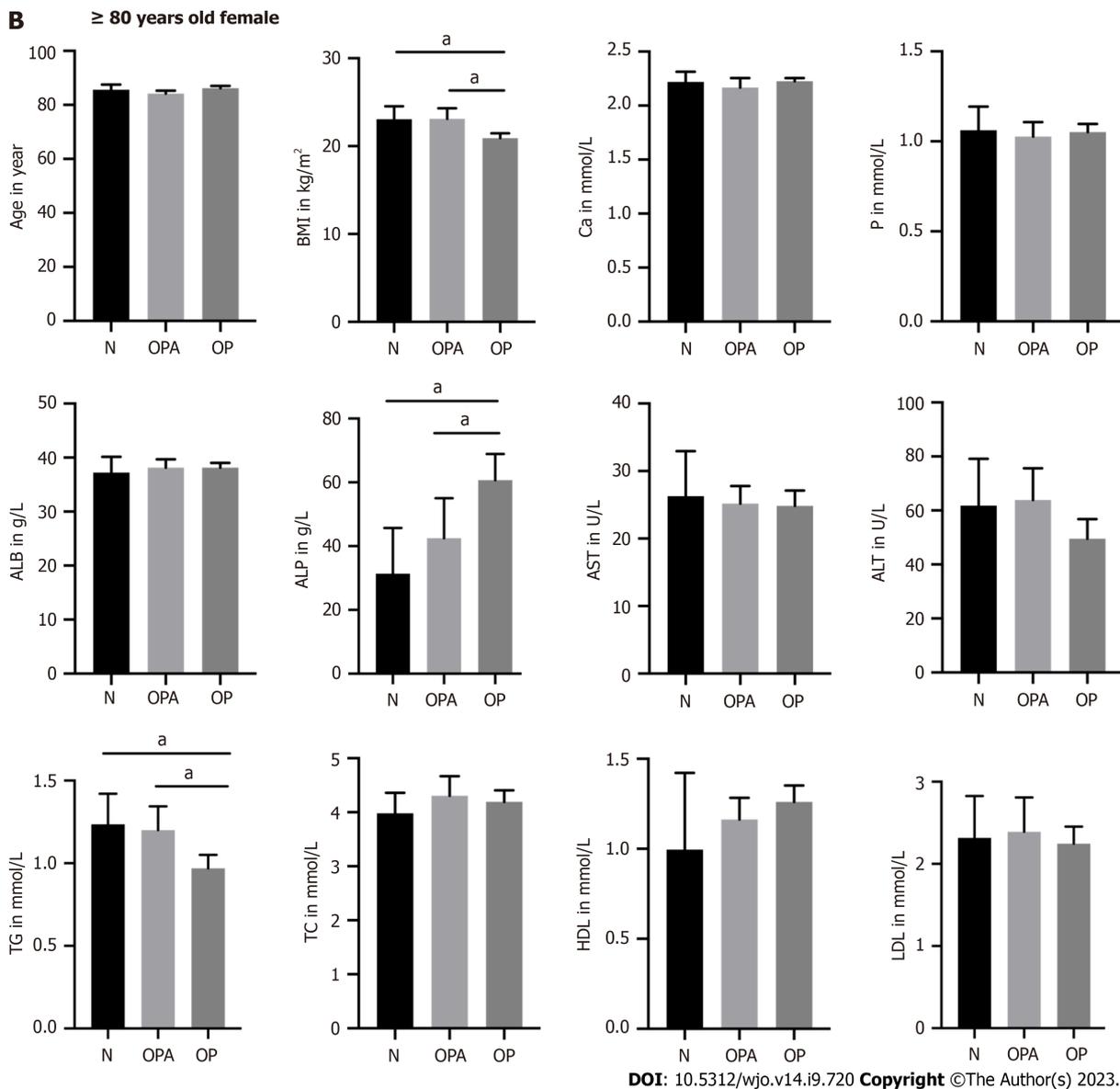


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**Figure 1** The differences of age, body mass index, calcium, phosphorus, albumin, alkaline phosphatase, aspartate aminotransferase, alanine transaminase, triglyceride, total cholesterol, high-density lipoprotein, and low-density lipoprotein in male patients. A: Presented the group of 65-79 years old man; N(N) = 35, N(OPA) = 50, N(OP) = 21; B: Presented the group of ≥ 80 years old man; N(N) = 13, N(OPA) = 31, N(OP) = 28. <sup>a</sup>*P* < 0.05, <sup>b</sup>*P* < 0.01 and <sup>c</sup>*P* < 0.001 as different significance levels. BMI: Body mass index; Ca: Calcium; P: Phosphorus; ALB: Albumin; ALP: Alkaline phosphatase; AST: Aspartate aminotransferase; ALT: Alanine transaminase; TG: Triglyceride; TC: Total cholesterol; HDL: High-density lipoprotein; LDL: Low-density lipoprotein; N: Normal bone mass; OPA: Osteopenia; OP: Osteoporosis.

**A 65-79 years old female**





**Figure 2** The differences of age, body mass index, calcium, phosphorus, albumin, alkaline phosphatase, aspartate aminotransferase, alanine transaminase, triglyceride, total cholesterol, high-density lipoprotein, and low-density lipoprotein in female patients. A: Presented the group of 65-79 years old female; N(N) = 19, N(OPA) = 65, N(OP) = 104; B: Presented the group of  $\geq 80$  years old female; N(N) = 17, N(OPA) = 38, N(OP) = 99. <sup>a</sup> $P < 0.05$ , <sup>b</sup> $P < 0.01$  and <sup>c</sup> $P < 0.0001$  as different significance levels. BMI: Body mass index; Ca: Calcium; P: Phosphorus; ALB: Albumin; ALP: Alkaline phosphatase; AST: Aspartate aminotransferase; ALT: Alanine transaminase; TG: Triglyceride; TC: Total cholesterol; HDL: High-density lipoprotein; LDL: Low-density lipoprotein; N: Normal bone mass; OPA: Osteopenia; OP: Osteoporosis.

female patients (Figure 3).

## DISCUSSION

In our study, we analyzed the clinical data of 520 patients aged  $\geq 65$  years. We found that osteoporotic patients showed significantly decreased BMI and TG levels in comparison with patients with normal bone mass. The number of patients diagnosed with osteoporosis is increasing annually, and previous studies have shown that many factors contribute to osteoporosis, including age, sex, BMI, and Ca, P, ALB, ALP, AST, ALT, TG, TC, HDL and LDL levels.

Previous studies have reported that many factors contribute to osteoporosis[3,22]. In our study, we found that age, sex, BMI, and ALP and TG levels were independent risk factors for osteoporosis. With increasing age, a series of factors are altered, such as a lack of sex steroids, declining levels of growth factors and changes in food intake, exercise and mechanical loading, leading to bone loss. Based on this, we classified the groups according to age. Regarding the relationship between sex and bone mass, previous studies have demonstrated that men tend to have a higher BMD at a later age and a lower rate of bone mass loss than women[23,24], suggesting that bone mass loss differs by sex. In our study, female patients in the 65-79- and  $\geq 80$ -year-old groups presented lower T scores than male patients. The reason for

Table 1 Univariate and multivariate analysis of related factors for osteoporosis

	Univariate analysis			P value	Multivariate analysis		
	Normal (n = 85)	Osteopenia (n = 184)	Osteoporosis (n = 251)		OR	95%CI	P value
Age (year old)	75.54 ± 8.22	76.31 ± 8.00	79.72 ± 7.62	< 0.001	-0.04	0.016-0.064	0.001
Gender (n)				< 0.001	1.34	0.968-1.720	< 0.001
Male	48	81	49				
Female	37	103	202				
BMI (kg/m <sup>2</sup> )	25.46 ± 3.32	23.43 ± 3.32	21.83 ± 3.10	< 0.001	-0.018	-0.373	< 0.001
≤ 18.5 (n)	1 (1.18)	9 (4.89)	38 (15.14)	< 0.001			
18.5-24 (n)	27 (31.76)	92 (50.00)	148 (58.96)				
≥ 24 (n)	57 (67.06)	83 (45.11)	65 (25.90)				
Ca (mmol/L)	2.21 ± 0.16	2.20 ± 0.15	2.22 ± 0.15	0.69			
P (mmol/L)	1.05 ± 0.29	1.02 ± 0.19	1.04 ± 0.20	0.56			
ALB (g/L)	38.21 ± 4.72	39.27 ± 4.26	38.49 ± 4.36	0.09			
ALP (U/L)	64.02 ± 41.37	59.40 ± 38.83	70.89 ± 39.63	0.01	0.01	0.006-0.015	< 0.001
AST (U/L)	26.19 ± 14.73	27.64 ± 15.36	24.83 ± 16.01	0.19			
ALT (U/L)	43.89 ± 30.07	48.50 ± 31.54	42.16 ± 31.87	0.11			
TG (mmol/L)	1.62 ± 0.83	1.35 ± 0.87	1.09 ± 0.47	< 0.001	-0.56	-1.132	< 0.001
TC (mmol/L)	4.48 ± 1.15	4.27 ± 1.06	4.22 ± 1.01	0.16			
HDL (mmol/L)	1.16 ± 0.31	1.21 ± 0.28	1.28 ± 0.44	0.1			
LDL (mmol/L)	2.67 ± 0.93	2.48 ± 0.84	2.40 ± 0.80	0.12			
CHD (n)	7	14	27	0.52			

BMI: Body mass index; Ca: Calcium; P: Phosphorus; ALB: Albumin; ALP: Alkaline phosphatase; AST: Aspartate aminotransferase; ALT: Alanine transaminase; TG: Triglyceride; TC: Total cholesterol; HDL: High-density lipoprotein; LDL: Low-density lipoprotein; CHD: Coronary heart diseases.

the differences in bone mass between sexes might be that hormones differ in males and females[23]. Moreover, significant differences were observed in the Ca, P, ALB, ALP, TC, HDL and LDL levels between men and women in the 65- to 79-year-old group. These results indicate that men and women present differences in many factors for osteoporosis. Cui *et al* [7] supported our results in their analysis of 1035 men and 3953 women, where they also showed significant differences in BMI and T scores, as well as in TG, TC, high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) levels, between men and women. According to their and our results, we classified the groups by sex and age (65-79 and ≥ 80 years old).

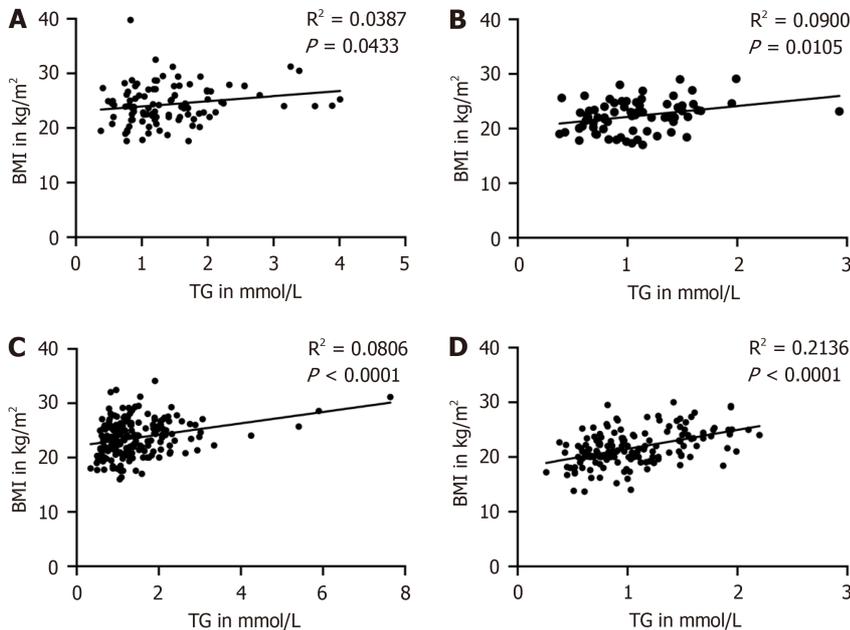
Previous studies have revealed the correlation among lipid profiles, BMI, and BMD[7,25,26]. In our study, we found that male and female osteoporotic patients showed significantly decreased BMI in the groups aged 65-79 and ≥ 80 years. Supporting our findings, many studies have reported an association between BMI and BMD. Alay *et al*[27] investigated 452 postmenopausal women in an outpatient clinic between 2012 and 2015 and observed that a decreased BMI was related to a lower BMD. In addition, Fawzy *et al*[28] analyzed 101 men and women and found that a decline in BMI was associated with a lower BMD. The possible mechanisms for the association between BMI and BMD might be that weight gain places greater static mechanical loads on the bones and increases various hormone levels, which are beneficial for bone mass and bone remodelling[26,29-31].

Moreover, our study demonstrated that male and female osteoporotic patients presented obviously decreased TG levels in the groups aged 65-79 years and ≥ 80 years. In addition, male and female osteoporotic patients also showed obviously decreased TC levels in the group aged 65-79 years. However, we did not find any significant differences in the HDL and LDL levels between the two groups in our study. Although previous studies have reported the association between serum lipid profiles and BMD, the literature is conflicting. Our study findings were in agreement with those of Cui *et al*[7], who showed that BMI and TG levels were significantly lower in patients with osteoporosis than in those with normal BMD. However, there was no significant difference in TC levels. In a meta-analysis, Chen *et al*[32] selected ten publications and investigated the relationship between lipid profiles (HDL, LDL, TG, and TC levels) and osteoporosis in postmenopausal women, finding significantly higher HDL and TC levels in the postmenopausal osteoporosis group than in the normal BMD group. Although the difference was not significant, postmenopausal osteoporosis patients presented with a lower TG level. Alfahal *et al*[33] also reported a lower TG level in postmenopausal individuals with osteoporosis

**Table 2** Male and female patients aged between 65 to 79 years old in related factors for osteoporosis

	Male (n = 106)	Female (n = 188)	P value
Age (year)	71.25 ± 4.39	72.18 ± 4.52	0.095
T-value	-1.51 ± 0.94	-2.5 ± 1.03	< 0.0001
BMI (kg/m <sup>2</sup> )	24.33 ± 3.52	23.63 ± 3.37	0.134
≤ 18.5 (n)	3 (2.83)	13 (6.91)	0.316
18.5-24(n)	48 (45.28)	85 (45.21)	
≥ 24 (n)	55 (51.89)	90 (47.88)	
Ca (mmol/L)	2.21 ± 0.13	2.25 ± 0.14	0.027
P (mmol/L)	1.00 ± 0.19	1.06 ± 0.14	0.01
ALB (g/L)	38.40 ± 4.11	39.67 ± 4.21	0.013
ALP (U/L)	69.29 ± 39.15	77.79 ± 35.53	0.032
AST (U/L)	26.86 ± 18.85	27.30 ± 19.34	0.258
ALT (U/L)	40.06 ± 27.97	38.94 ± 28.56	0.953
TG (mmol/L)	1.39 ± 0.73	1.45 ± 0.91	0.727
TC (mmol/L)	4.15 ± 0.95	4.52 ± 1.11	0.005
HDL (mmol/L)	1.13 ± 0.26	1.33 ± 0.45	< 0.001
LDL (mmol/L)	2.42 ± 0.83	2.68 ± 0.86	0.048

BMI: Body mass index; Ca: Calcium; P: Phosphorus; ALB: Albumin; ALP: Alkaline phosphatase; AST: Aspartate aminotransferase; ALT: Alanine transaminase; TG: Triglyceride; TC: Total cholesterol; HDL: High-density lipoprotein; LDL: Low-density lipoprotein.



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**Figure 3** The correlation between body mass index and triglyceride in male and female patients. A: Presented the group of 65-79 years old male patients; n = 106; B: Presented the group of ≥ 80 years old male patients; n = 72; C: Presented the group of 65-79 years old female patients; n = 188; D: Presented the group of ≥ 80 years old female patients; n = 154. P < 0.05 as a different significance level. BMI: Body mass index; TG: Triglyceride.

**Table 3 Male and female patients aged  $\geq 80$  years old in related factors for osteoporosis**

	Male (n = 72)	Female (n = 154)	P value
Age (year)	85.60 $\pm$ 4.08	85.65 $\pm$ 33.89	0.839
T-value	-2.06 $\pm$ 1.21	-2.94 $\pm$ 1.29	< 0.0001
BMI (kg/m <sup>2</sup> )	22.34 $\pm$ 3.26	21.68 $\pm$ 3.12	0.15
$\leq 18.5$ (n)	10 (13.89)	22 (14.29)	0.829
18.5-24 (n)	41 (56.94)	93 (60.39)	
$\geq 24$ (n)	21 (29.17)	39 (25.32)	
Ca (mmol/L)	2.20 $\pm$ 0.17	2.21 $\pm$ 0.19	0.234
P (mmol/L)	1.01 $\pm$ 0.28	1.09 $\pm$ 0.58	0.092
ALB (g/L)	38.19 $\pm$ 4.34	38.04 $\pm$ 4.68	0.823
ALP (U/L)	56.21 $\pm$ 38.95	52.95 $\pm$ 40.44	0.455
AST (U/L)	23.61 $\pm$ 9.93	25.08 $\pm$ 10.77	0.238
ALT (U/L)	45.61 $\pm$ 28.78	54.45 $\pm$ 36.12	0.06
TG (mmol/L)	1.07 $\pm$ 0.44	1.08 $\pm$ 0.49	0.857
TC (mmol/L)	4.03 $\pm$ 0.99	4.20 $\pm$ 1.03	0.171
HDL (mmol/L)	1.17 $\pm$ 0.30	1.21 $\pm$ 0.32	0.425
LDL (mmol/L)	2.31 $\pm$ 0.78	2.29 $\pm$ 0.78	0.926

BMI: Body mass index; Ca: Calcium; P: Phosphorus; ALB: Albumin; ALP: Alkaline phosphatase; AST: Aspartate aminotransferase; ALT: Alanine transaminase; TG: Triglyceride; TC: Total cholesterol; HDL: High-density lipoprotein; LDL: Low-density lipoprotein.

compared with individuals with normal bone mass individuals. However, Bijelic *et al*[34] evaluated lipid profiles and BMI in 100 postmenopausal osteoporotic patients and patients with normal BMD. They proved that in postmenopausal patients, osteoporosis was associated with LDL, TC, and TG levels. Contrary to our results, they showed increased TG levels in osteoporotic patients compared with those with a normal BMD. The reason might be that, in their study, there were 72 overweight patients in the osteoporosis group and 54 overweight patients in the normal BMD group. However, Alay *et al*[27] did not observe significant differences in HDL, LDL, TG, and TC levels between groups with normal bone mass and osteoporosis. BMI and TG levels were independent risk factors for osteoporosis in our study. Moreover, we also observed a positive correlation between BMI and TG levels in the groups of male and female patients aged 65-79 and  $\geq 80$  years. These results suggest a positive relationship among BMI, TG levels and BMD.

It has been reported that lipids may be a predisposing factor for osteoporosis and are associated with bone fragility [11], and TG metabolism is considered to be correlated with bone metabolism. Dragojević *et al*[35] performed a gene expression study by analysing bone tissue from 50 patients with osteoporosis and 62 controls. They reported that osteoporosis patients had decreased osteoblastogenesis, increased osteoclastogenesis, and lower TG metabolism than controls. TGs are considered an important form for the storage of fatty acids. Fatty acids are essential components of all lipids and are involved in producing energy in all vertebrates; fatty acid metabolism plays essential roles in osteoblast and osteoclast function and activities as well as in bone remodelling[36-38]. This could be one explanation for the relationship between serum TG levels and bone remodelling. However, the underlying mechanism between TG metabolism and bone metabolism remains unclear, and more studies should be performed in the future.

In addition, we did not observe significant differences in other factors for osteoporosis, such as Ca, P, AST, ALT and ALB levels, between the osteoporosis and control groups in our study. Regarding the association between serum Ca and P levels and osteoporosis, many studies have shown different results. Our study reported that serum Ca and P levels were normal in postmenopausal women with or without osteoporosis. This may be because the levels of Ca and P in serum may not reflect their storage in bones. Serum Ca and P levels are regulated, and homeostasis is maintained in serum[39,40]. In previous studies, nutrition was reported to be related to osteoporosis, and serum ALB levels were lower in patients with osteoporosis[41,42]. By analysing the serum ALB levels of 15539 individuals, hypoalbuminemia (serum ALB less than 3.5 g/dL) was found to be associated with osteoporosis[42]. However, the mean serum ALB levels were more than 35 g/L in patients with normal bone mass and osteoporotic patients and did not show differences between groups in our study. This might be the reason why serum ALB was not a factor for diagnosing osteoporosis in our study. AST and ALT are liver enzymes, and they were also reported to be associated with osteoporosis. In agreement with our study, Do *et al*[9] selected 7160 subjects to analyse the association between liver enzymes and BMD in Koreans. They also did not show differences in the association of AST and ALT with femur BMD. We discovered that ALP was an independent factor for osteoporosis, and osteoporotic female patients aged  $\geq 80$  years showed significantly increased ALP levels. Supporting our results, increased serum ALP levels in postmenopausal women indicate high bone turnover and

are helpful for diagnosing osteoporosis[43-45].

This study investigated the interplay between BMI, lipid profile, and bone mass within a population vulnerable to brittle fractures. Our research has several strengths. Firstly, our study utilized blood samples collected from fragility fracture patients upon admission to assess pertinent lipid metabolism markers. Secondly, individuals with fragility fractures frequently experience bone loss or osteoporosis. Our findings introduce a novel perspective for future endeavours in osteoporosis and fragility fracture prevention. Furthermore, our hierarchical analysis provides preliminary results, enhancing the generalizability of our research outcomes.

Nonetheless, our research bears certain limitations. Firstly, being a single-centre study, not all patients had lipid metabolism indicator data available for analysis due to admission discrepancies among fragility fracture patients, which resulted in a significant reduction in sample size. Among patients undergoing DXA assessments, the T-value of the proximal femur was the only site measurement employed for standardization, with lumbar and radius measurements being omitted. Furthermore, follow-up data for the study cohort is absent, impeding outcome comparison. Moving forward, we aspire to extend this discourse through a multicentre, large-sample study. Additionally, we intend to investigate the nexus between BMI, lipid profile, and bone mass *via* prospective studies involving nutritional interventions in patients.

## CONCLUSION

In conclusion, osteoporotic patients showed significantly decreased BMI and TG levels in comparison with patients with normal bone mass in our study. These results indicate an association between TG metabolism and bone metabolism and provide a new method for the treatment of osteoporosis.

## ARTICLE HIGHLIGHTS

### Research background

The increasing incidence of osteoporosis and low bone mass, affecting a significant portion of individuals aged 50 years or older in China, underscores the urgent need to address this public health concern. While obesity's potential protective role and the complex interplay between body mass index (BMI), lipid profiles, and bone health are subjects of recent investigation, their specific impact on populations with osteoporosis and fragility fractures remains relatively unexplored.

### Research motivation

The relationship between BMI, bone mass, and lipid profiles in populations with osteoporosis and fragility fractures remains understudied.

### Research objectives

This study aims to shed light on the potential impact of weight gain and lipid profiles on bone health in individuals with fragility fractures which may provide a new method for the treatment of osteoporosis.

### Research methods

This retrospective study conducted at a single orthopaedic trauma center between January 2017 and December 2020 included participants aged 65 years and above with diagnosed fractures in specific region. Participants' comprehensive clinical data, including gender, age groups, BMI ranges, DXA scores, and laboratory measurements, were collected and analyzed using statistical software. Data were analyzed using IBM SPSS and GraphPad Prism software, employing t-tests, nonparametric tests, one-way ANOVA, multiple linear regression, and Pearson correlation tests (<sup>a</sup> $P < 0.05$ , <sup>b</sup> $P < 0.01$ , <sup>c</sup> $P < 0.001$ , <sup>d</sup> $P < 0.0001$  denoting significance) after assessing normality with the Shapiro-Wilk test.

### Research results

In this study involving 520 participants aged  $\geq 65$  years, distinct gender and age-related disparities were observed in osteoporosis prevalence and associated factors. While a significant divergence in age, sex, BMI, alkaline phosphatase (ALP), and triglyceride (TG) concentrations was noted among normal, osteopenic, and osteoporotic groups, multivariate analysis revealed age, sex, BMI, ALP, and TG concentrations as independent risk factors for osteoporosis. Differential correlations between BMI and bone health parameters, along with lipid profiles, were elucidated across age and gender cohorts. Notably, these findings underscore the intricate interplay between metabolic and skeletal factors in the context of osteoporosis.

### Research conclusions

In conclusion, osteoporotic patients showed significantly decreased BMI and TG levels in comparison with patients with normal bone mass in our study.

### Research perspectives

These results indicate an association between TG metabolism and bone metabolism and provide a new method for the

treatment of osteoporosis.

## FOOTNOTES

**Author contributions:** Chen XX and Tian CW contributed equally to this work; Chen XX and Tian CW designed the study, including the research questions and methodology; Bai LY, Zhao YK, Zhang C, Shi L, Zhang YW, Xie WJ, Zhu HY, Chen H assisted in study design, contributed to data collection and management; Tian CW performed data analysis, provided critical insights into data interpretation; Rui YF supervised the entire study, provided guidance on research design and took a lead in manuscript writing and revision; All authors have read and approve the final manuscript.

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**Data sharing statement:** The data presented in this study are available upon reasonable request to qualified researchers for the purpose of academic and scientific collaboration. Requests for data access should be directed to the corresponding author at [ruiyunfeng@126.com](mailto:ruiyunfeng@126.com).

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**Country/Territory of origin:** China

**ORCID number:** Liu Shi 0000-0002-8990-4019; Yun-Feng Rui 0000-0001-9019-5531.

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**L-Editor:** A

**P-Editor:** Xu ZH

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