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Association between triglycerides and lumbar bone mineral density in Chinese patients with osteoporotic fractures: a retrospective cross-sectional study

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The association between lumbar bone mineral density (BMD) and triglyceride (TG) levels has been extensively studied; however, the results remain controversial. Therefore, this research aimed to elucidate the association of TG levels with lumbar BMD in patients with osteoporotic fractures (OPFs) who have undergone surgery. This cross-sectional study analyzed 3,558 OPF patients (aged 50 years and above) who were admitted to the First People's Hospital of Kunshan and assessed their TG levels, lumbar BMD, and other variables. The outcome variable of this research was bone density, whereas the baseline glycerol trihydrate levels were considered as the exposure variable. An analysis adjustment was conducted for various covariates, including age, gender, body mass index (BMI), and other baseline laboratory and clinical results. Furthermore, the potential non-linear relationships were assessed via the smooth curve fitting, and threshold effect analyses. The mean age of 3,558 included OPF patients was 68.87 ± 10.55 years. In the fully adjusted multivariate regression analysis, a positive correlation was found between TG levels and lumbar BMD (β = 0.015, 95% CI: 0.001–0.028, *p* = 0.033). Furthermore, the threshold effect analysis revealed a curvilinear relationship between TG levels and lumbar BMD, with a turning point at 1.26 mmol/L. Moreover, on both sides of the turning point, different patterns were observed. On the left side, TG levels were positively correlated with lumbar BMD. However, despite higher TG levels, the differences in lumbar BMD on the right side of the turning point, were not statistically significant, indicating a lack of significant association (*p* = 0.712). In summary, this research indicated that in OPF patients, higher TG levels were significantly positively associated with lumbar BMD. Furthermore, there was a threshold value of 1.26 mmol/L, indicating that TG levels in OPF patients with concomitant hypertriglyceridemia should be maintained within the normal range, and reducing TG levels below 1.26 mmol/L requires continuous monitoring. This approach effectively controls TG levels without adversely impacting lumbar BMD.

Keywords Triglyceride, Lumbar bone mineral density, Osteoporotic fracture

Osteoporosis (OP) is one of the most prevalent metabolic bone disorders in elderly population[1]. It is primarily characterized by bone microarchitecture deterioration and reduced bone mass/mineral density (BMD)[2–4]. OP increases the risk of fractures in older adults, and osteoporotic fractures (OPFs) are a common cause of morbidity and mortality[5,6]. Because of fragility fractures, OP is considered a major health concern, significantly affecting morbidity, socioeconomic status, and mortality[7–9]. The 2D method of dual-energy X-ray absorptiometry is the gold standard technique for OP diagnosis[10,11].

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It has been observed that in the elderly population arteriosclerosis and OP are co-morbidities[12]. Furthermore, dyslipidemia, disruptions in triglyceride (TG) metabolism, has been indicated as a major cause of arteriosclerosis[13,14]. However, the association between TG and BMD has remain elusive.

Some studies have suggested a negative TG and BMD association in specific populations and propose that higher TG levels might be correlated with lower BMD and increased risk of OP. This hypothesis is supported by the notion that dyslipidemia can disrupt the balance of bone remodeling, affecting the activity and production of osteoclasts and osteoblasts, the cells responsible for bone resorption and formation[15–17].

However, several other studies have indicated a positive correlation between BMD and serum TG levels, proposing that higher TG levels may indicate better overall metabolic health, in turn positively affecting BMD. It is hypothesized that TG, as an energy source, essentially supports the metabolic demands of bone tissue and promotes bone mineralization[13,18].

Thus, understanding the precise role of TG in OP could significantly help the diagnosis, prevention, and management of this debilitating condition. Therefore, this investigation aimed to elucidate the association between BMD and TG levels in OPF patients aged ≥ 50 years.

Materials and methods

Ethical consideration

The study was authorized by the Ethical Board of the Affiliated Kunshan Hospital of Jiangsu University, Suzhou, China (approval # 2021-06-015-K01) and followed the Helsinki Declaration. To ensure an unbiased investigation, patients' identities were not revealed and a signed written consent form was acquired from all the participants.

Study population

This retrospective cross-sectional investigation analyzed the data of 3558 OPF patients who underwent surgery or were hospitalized at the Kunshan Hospital, affiliated with Jiangsu University, Suzhou, China, between January 2017 to July 2022. All patient's blood was tested during hospitalization. The OP was diagnosed based on the following parameters: (1) The presence of bone fractures and instability without any accompanying bone metabolic disorders, and (2) The standard BMD T-score of -2.5 or below, even in the absence of a bone fracture[19]. Furthermore, patients (1) with missing or incomplete records, (2) with multiple or pathological hip fractures, (3) who are diagnosed with other diseases that interfere with bone metabolism, (4) with prolonged use of drugs that affect bones, such as glucocorticoids, and (5) TG < 6 were excluded from the study[13].

Exposure and outcome variables

The serum TG levels were assessed in 759 OPF patients using the GPO-POD method via the Beckman AU5800 automated biochemical analyzer. Furthermore, lumbar BMD was also measured in these patients using dual-energy X-ray absorptiometry (DXA) with a Hologic dual-energy X-ray bone density instrument (Discovery Wi, Hologic Inc, USA). For TG content and lumbar BMD assessment, fasting blood was collected within 24 h of admission, before surgery. A skilled operator collected the samples using identical equipment according to established protocols. BMD analysis was performed in lumbar fracture patients and their average of the vertebral bodies was assessed other than the affected vertebral body.

Covariate variables

The covariate variables such as age, sex, body mass index (BMI), magnesium, sodium, phosphorus, platelet, neutrophil, monocyte, apolipoprotein A, creatinine (CR), uric acid (UA), American Society of Anesthesiologists (ASA) score and fracture category were assessed. Fasting blood samples were collected and all the clinical indicators were assessed within 3 days after admission.

Statistical analyses

The demographics, laboratory tests, and clinical outcomes data were indicated as median with the interquartile range (the 25th and 75th percentiles) or mean ± standard deviation (SD). For each category, the data were presented in the form of frequencies (expressed as percentages). For categorical data analysis, Pearson's chi-square or Fisher's exact test was carried out for univariate analysis. For normally and not-normal distributed continuous data, independent samples t-test and Mann-Whitney U test were carried out utilized, respectively. The association between the attributes of OPFs and the lumbar BMD was also investigated using univariate analysis.

The generalized estimating equation (GEE) was employed to appropriately adjust for covariates and investigate the independent association between lumbar BMD and TG levels in OPF patients. The developed models included unadjusted (Model 1), slightly adjusted (Model 2), and fully adjusted (Model 3) models. First, the presence of collinearity among the covariates was detected via the variance inflation factor (VIF) analysis. Then, these elements were modified according to the following parameters: (1) A modification in the matched odds ratio (OR) by ≥ 10% upon the addition or removal of covariates in the basic or full model, respectively, and (2) Variables satisfying criterion 1 or had a univariate model with p-value < 0.1[20]. Model 3 employed both criteria 1 and criteria 2 to adjust the covariates. Thus, three models were ultimately developed: Model 1 (left unadjusted), Model 2 (minimally adjusted), which required covariate adjustments for age, and gender, and Model 3, which additionally included covariates such as magnesium, sodium, phosphorus, platelet, neutrophil, monocyte, apolipoprotein A, CR, UA, ASA score and fracture category.

The probable non-linear associations were assessed via the Generalized Additive Model (GAM). Afterward, the resulting smoothing curve's threshold effects were evaluated using a two-piecewise linear regression model. Furthermore, the inflection point was determined with the help of a recursive approach, and a maximum likelihood model was employed when these curves indicated a clear ratio[21]. Subgroup analyses were conducted

to assess the study's robustness and examine differences among patient subgroups by their stratification based on specific covariates. Likelihood ratio tests (LRT) were employed to analyze the interactions and modifications within the subgroups.

All the statistical measurements were performed using Empower Stats from X&Y Solutions, Inc., MA, USA (http://www.empowerstats.com) and R packages from The R Foundation (http://www.R-project.org). The significant threshold of the two-tail test was $p < 0.05$.

Results

Clinical and demographic traits of subjects

According to the eligibility criteria depicted in Figs. 1 and 759 patients from January 1, 2017, to July 27, 2022 were included in this research analysis. The baseline characteristics of the hospitalized patients ($n = 759$, 72.46% female and 27.54% male, mean age 68.87 ± 10.55 years) are summarized in Table 1. The subjects in this study indicated mean TG and lumbar BMD values of 1.21 ± 0.72 mmol/L and 0.74 ± 0.15 g/cm^2, respectively.

Univariate analysis of lumbar BMD

To elucidate the association of lumbar BMD with covariate variables, a univariate analysis was carried out (Table 2), which indicated no significant relationships between the investigated variables and lumbar BMD in OPF patients.

Relationship analysis between triglyceride and lumbar BMD

Altogether, 3 models were utilized to analyze the correlation between TG levels and lumbar BMD in OPF patients (Table 3). The unadjusted Model 1 indicated a significant correlation between lumbar BMD and TG levels (β = 0.016, 95% CI: 0.002–0.030, $p = 0.029$). In Model 2, after adjusting the variables (age and sex), consistent relationships were observed and TG was significantly associated with lumbar BMD (β = 0.014, 95% CI: 0.001–0.027, $p = 0.036$). Model 3 included further adjustments for magnesium, sodium, phosphorus, platelet, neutrophil, monocyte, apolipoprotein A, CR, UA, ASA score, and fracture category, which consistently indicated a significant positive correlation between TG levels and lumbar BMD (β = 0.015, 95% CI: 0.001–0.028, $p = 0.033$).

Further subgroup analysis was performed to assess the robustness of Model 3 by categorizing OPF patients based on various characteristics such as age, sex, BMI, magnesium, sodium, phosphorus, platelet, neutrophil, monocyte, apolipoprotein A, CR, UA, ASA score, and fracture. Covariates that were not utilized for stratification were adjusted (Table 4). Furthermore, the interaction analysis indicated that UA levels influenced the correlation between TG levels and lumbar BMD ($p = 0.007$) (Fig. 2). In patients with low UA levels (≤271 μmol/L), the β coefficient (β = 0.033, 95% CI: 0.013–0.054, $p < 0.001$) representing the correlation between TG and lumbar BMD was significantly consistent with the main findings of this study. However, in high UA patients (> 271 μmol/L), the association of increasing TG levels with corresponding increasing lumbar BMD was not clarified. In addition, the results of other analyses were also consistent with the pattern observed in the main study result, and no significant interactions due to stratification were detected.

Spline smoothing plot and threshold analysis

Graphical techniques were also employed to assess whether the correlation between TG and lumbar BMD was linear or nonlinear (Fig. 3). The GAM estimation revealed that, after accounting for covariate variables, there were distinct nonlinear relationships between TG and lumbar BMD in OPF patients. These associations were modeled using segmented linear regression, with the identified breakpoints (K-values) of 1.26 (Table 5). To the left of the thresholds, a strong positive correlation between TG and lumbar BMD [0.061 (95% CI: 0.024–0.098, $p = 0.001$)] was observed. However, the effect size on the right side of this threshold was − 0.004 (95% CI: -0.023–0.016, $p = 0.712$).

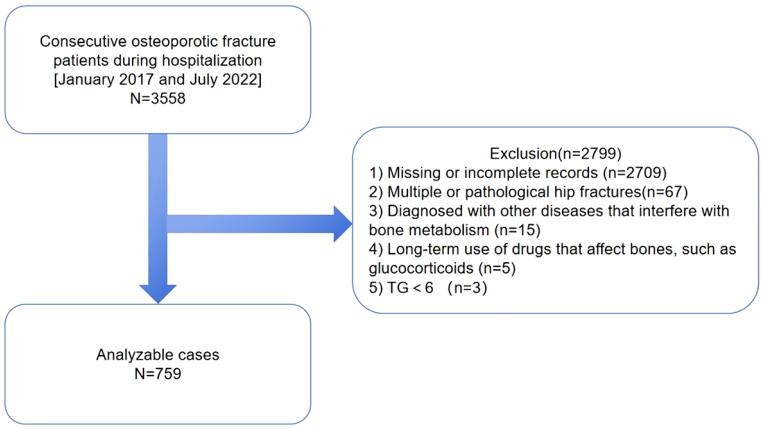

Fig. 1. A schematic representation of the study design.

Characteristics	Mean (SD) Median (Q1-Q3)[a]
Age, years	68.87 (10.55) 68.00 (61.00–77.00)
BMI, kg/m^2	22.95 (3.30) 22.89 (20.69–24.99)
Magnesium, mmol/L	0.89 (0.10) 0.89 (0.82–0.96)
Sodium, mmol/L	140.99 (2.93) 141.20 (139.50-142.60)
Phosphorus, mmol/L	1.08 (0.20) 1.08 (0.97–1.19)
Platelet, ×10^9/L	175.62 (63.95) 166.00 (135.00-208.00)
Neutrophil, ×10^9/L	6.41 (3.15) 5.76 (4.20-8.00)
Monocyte, ×10^9/L	0.49 (0.24) 0.50 (0.30–0.60)
Apolipoprotein A, g/L	1.20 (0.23) 1.17 (1.04–1.33)
CR, umol/L	67.63 (31.92) 63.00 (53.00–75.00)
UA, umol/L	282.78 (96.00) 272.00 (219.00-331.50)
TG, mmol/L	1.21 (0.72) 0.98 (0.73–1.45)
Lumbar BMD, g/cm^2	0.74 (0.15) 0.73 (0.64–0.83)
	N (%)
Sex, N (%)	
Female	550 (72.46%)
Male	209 (27.74%)
ASA score, N (%)	
1	67 (8.83%)
2	521 (68.64%)
≥3	171 (22.53%)
Fracture category, N (%)	
Thoracic vertebra	149 (19.63%)
Lumbar vertebra	293 (38.60%)
Wrist	17 (2.24%)
Proximal humerus	57 (7.51%)
Thighbone	243 (32.02%)

Table 1. Characteristics of study participants. [a]For continuous variables. Abbreviations: SD, standard deviation; Q1, first quartile; Q3, third quartile; CI, confidence interval; BMI, body mass index; CR, creatinine; UA, uric acid; TG, triglycerides; BMD, bone mineral density; ASA, American Society of Anesthesiologists.

Discussion

This study analyzed the data of OPF patients (age ≥ 50) enrolled at Kunshan Hospital affiliated with Jiangsu University collected between January 2017 to July 2022 to elucidate the correlation between TG and lumbar BMD. The results demonstrated a significant positive correlation between TG and lumbar BMD on the left side of the inflection point (1.26 mmol/L), while a non-significant negative correlation on the right side.

Hypertriglyceridemia is one of the most common lipid abnormalities[22]. Several studies have been performed on elevated TG levels[23–25]. The association between TG and BMD has been extensively investigated in the general population and has yielded varying conclusions. Furthermore, a significant correlation between elevated TG levels and decreased BMD or OP has been observed[13]. In this research, a multiple regression equation was employed to elucidate the relationship between TG and lumbar BMD, which indicated a positive correlation ($\beta = 0.015$, 95% CI: 0.001–0.028, $p = 0.033$). Furthermore, the smooth curve fitting and threshold effect analyses revealed a turning point in the association between TG and lumbar BMD. When TG levels were below 1.26 mmol/L, an elevated TG level was significantly associated with increased lumbar BMD. At one side of the inflection point, a slight negative correlation was observed.

Fat is an essential component of the human body and reflects the nutritional status of an individual. Here, a positive correlation was observed between lower TG levels and increased lumbar BMD, consistent with the findings of previous research[26–28]. Furthermore, increased TG levels are often associated with endocrine disruption, potentially influencing the levels of various hormones, including sex, thyroid, and growth hormones, as well as cortisol. These hormonal disruptions can have negative effects on the skeletal system, leading to bone loss and decreased BMD[29,30]. Moreover, high TG levels may trigger inflammatory responses and oxidative stress[31], both of which are closely associated with disturbances in bone metabolism.

These findings provide valuable insights for clinical practice. In patients with OPF and hypertriglyceridemia, lipid-lowering medications should be employed to control TG levels within the normal range. However, it is not recommended to reduce TG below 1.26 mmol/L as this may have adverse effects on the OPF prognosis and prevent increases in lumbar BMD. Because of the relatively low contribution of TG levels to lumbar BMD, once the concentration exceeds the threshold, patients with hypertriglyceridemia should aim to reduce their TG levels to 1.26 mmol/L. This approach can control blood TG levels effectively while minimizing any detrimental impact on lumbar BMD.

Characteristics	Statistics[a]	Lumbar BMD β (95%CI) *P*-value
Age, years	68.87 ± 10.55	-0.004 (-0.005, -0.003) < 0.001
BMI, kg/m^2	22.95 ± 3.30	0.011 (0.008, 0.014) < 0.001
Magnesium, mmol/L	0.89 ± 0.10	0.073 (-0.031, 0.177) 0.169
Sodium, mmol/L	140.99 ± 2.93	-0.003 (-0.007, 0.000) 0.061
Phosphorus, mmol/L	1.08 ± 0.20	-0.007 (-0.059, 0.046) 0.803
Platelet, ×10^9/L	175.62 ± 63.95	0.000 (-0.000, 0.000) 0.962
Neutrophil, ×10^9/L	6.41 ± 3.15	0.001 (-0.002, 0.005) 0.435
Monocyte, ×10^9/L	0.49 ± 0.24	0.002 (-0.041, 0.045) 0.925
Apolipoprotein A, g/L	1.20 ± 0.23	0.072 (0.027, 0.116) 0.002
CR, umol/L	67.63 ± 31.92	-0.000 (-0.001, -0.000) 0.017
UA, umol/L	282.78 ± 96.00	0.000 (-0.000, 0.000) 0.475
TG, mmol/L	1.21 ± 0.72	0.016 (0.002, 0.030) 0.029
Sex, N (%)		
Female	55 (72.46%)	Reference
Male	209 (27.54%)	0.124 (0.102, 0.145) < 0.001
ASA score, N (%)		
1	67 (8.83%)	Reference
2	521 (68.64%)	-0.066 (-0.102, -0.029) < 0.001
≥ 3	171 (22.53%)	-0.106 (-0.147, -0.065) < 0.001
Fracture category, N (%)		
Thoracic vertebra	149 (19.63%)	Reference
Lumbar vertebra	293 (38.60%)	0.040 (0.011, 0.068) 0.007
Wrist	17 (2.24%)	0.078 (0.005, 0.151) 0.036
Proximal humerus	57 (7.51%)	0.063 (0.019, 0.108) 0.005
Thighbone	243 (32.02%)	0.036 (0.007, 0.066) 0.017

Table 2. Univariate analysis for lumbar BMD. [a]For continuous variables. [b]The dependent variable was bone turnover markers and β is the result of univariate analysis for lumbar BMD. Abbreviations: TG, triglycerides; BMD, bone mineral density; BMI, body mass index; CR, creatinine; UA, uric acid; ASA, American Society of Anesthesiologists.

	Model 1[a] *N* = 759 β (95%CI) *P*-value	Model 2[b] *N* = 759 β (95%CI) *P*-value	Model 3[c] *N* = 757 β (95%CI) *P*-value
Lumbar BMD	0.016 (0.002, 0.030) 0.029	0.014 (0.001, 0.027) 0.036	0.015 (0.001, 0.028) 0.033

Table 3. Association between TG and lumbar BMD in different models. [a]No adjustment. [b]Adjusted for age, sex. [c]Adjusted for age, sex, BMI, magnesium, sodium, phosphorus, platelet, neutrophil, monocyte, apolipoprotein A, CR, UA, ASA, fracture category. Abbreviations: CI, confidence interval; TG, triglycerides; BMD, bone mineral density; BMI, body mass index; CR, creatinine; UA, uric acid; ASA, American Society of Anesthesiologists.

Study advantages and limitations

Compared to previous studies, this research has several advantages. (1) This research comprised OPF patients aged 50 years and above, which is inconsistent with prior research. (2) The results of this investigation indicated a positive correlation between TG and lumbar BMD, with a turning point at 1.26 mmol/L, providing a baseline value for clinical considerations. (3) This investigation identified an interaction effect of UA on the association of TG with lumbar BMD, which has not been previously addressed in the literature.

Despite the advantages, this study has certain limitations. (1) The study was cross-sectional, and thus does not permit inferences concerning time and causality relationships. Further mechanistic insights and large-scale prospective studies are needed to elucidate the specific underlying mechanisms. We plan to conduct longitudinal analyses in our future research, involving long-term patient follow-ups, to obtain more comprehensive and reliable results. This would further advance the understanding of the relationship between serum triglycerides and lumbar spine bone density in the elderly osteoporotic population. (2) Other potential covariates, such as treatment modalities during hospitalization, were not considered. These confounding factors may also influence

Subgroup	*N*	Lumbar BMD[a] β (95% CI) *P*-value	*P*-value for interaction
Age, years, N (%)			0.835
Low	397	0.012 (-0.006, 0.030) 0.202	
High	362	0.018 (-0.002, 0.038) 0.083	
Sex, N (%)			0.586
Female	550	0.012 (-0.004, 0.027) 0.141	
Male	209	0.020 (-0.010, 0.043) 0.225	
BMI, kg/m^2, N (%)			0.815
Low	378	0.019 (-0.001, 0.038) 0.061	
High	381	0.013 (-0.006, 0.032) 0.181	
Magnesium, mmol/L			0.651
Low	344	0.009 (-0.012, 0.030) 0.402	
High	415	0.020 (0.003, 0.038) 0.025	
Sodium, mmol/L			0.748
Low	341	0.013 (-0.007, 0.034) 0.208	
High	418	0.018 (0.000, 0.036) 0.048	
Phosphorus, mmol/L			0.159
Low	367	0.027 (0.006, 0.048) 0.014	
High	392	0.006 (-0.011, 0.023) 0.501	
Platelet, $\times 10^9$/L			0.651
Low	379	0.014 (-0.007, 0.034) 0.201	
High	378	0.015 (-0.003, 0.033) 0.102	
Neutrophil, $\times 10^9$/L			0.569
Low	399	0.020 (0.001, 0.039) 0.043	
High	358	0.008 (-0.011, 0.027) 0.414	
Monocyte, $\times 10^9$/L			0.052
Low	378	0.004 (-0.014, 0.022) 0.685	
High	379	0.030 (0.010, 0.050) 0.004	
Apolipoprotein A, g/L			0.509
Low	365	0.018 (-0.004, 0.039) 0.107	
High	394	0.012 (-0.005, 0.030) 0.175	
CR, umol/L			0.041
Low	375	0.033 (0.013, 0.054) 0.001	
High	384	-0.000 (-0.018, 0.018) 0.975	
UA, umol/L			0.007
Low	377	0.041 (0.020, 0.063) < 0.001	
High	382	0.002 (-0.019, 0.014) 0.801	
ASA score, N (%)			0.671
1	67	0.034 (-0.008, 0.075) 0.112	
2	521	0.011 (-0.005, 0.027) 0.164	
≥3	171	0.023 (-0.008, 0.055) 0.153	
Fracture category, N (%)			0.303
Thoracic vertebra	149	0.006 (-0.026, 0.039) 0.706	
Lumbar vertebra	293	0.004 (-0.017, 0.025) 0.710	
Wrist	17	0.111 (0.012, 0.210) 0.273	
Proximal humerus	57	0.002 (-0.041, 0.046) 0.920	
Thighbone	243	0.039 (0.014, 0.064) 0.003	

Table 4. Subgroup analysis between TG and lumbar BMD. [a]Patients were stratified based on age; sex; BMI; magnesium; sodium; phosphorus; platelet; neutrophil; monocyte; apolipoprotein A; CR; UA; ASA; fracture category, and additional covariates not included in the stratification were adjusted for in the analysis. Abbreviations: CI, confidence interval; BMI, body mass index; CR, creatinine; UA, uric acid; TG, triglycerides; BMD, bone mineral density; ASA, American Society of Anesthesiologists.

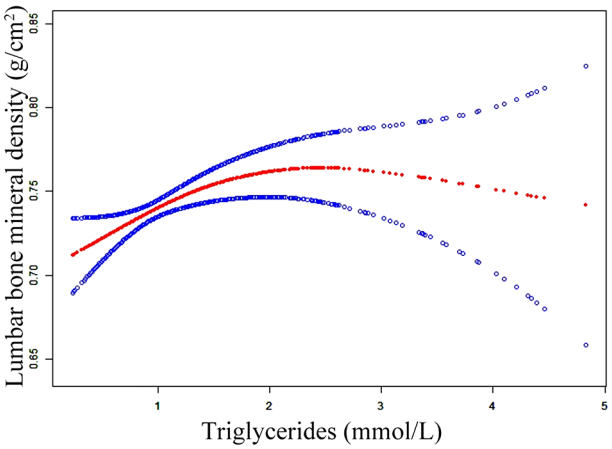

Fig. 2. In the high uric acid group (≤271umol/L) and low uric acid group (>271umol/L), TG exhibited distinct trends in relation to lumbar BMD.

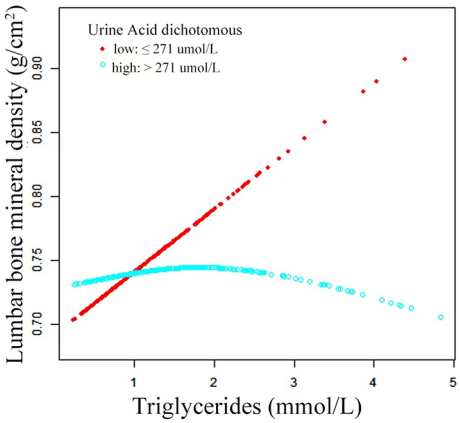

Fig. 3. Adjusted Smoothed Curve Analysis Revealing the Interplay Between TG and Lumbar BMD: GAM identified a threshold non-linear correlation between TG and lumbar BMD in OPFs. The upper and bottom curves depict the extent of the 95% confidence interval, whereas the middle curve illustrates the link between TG and lumbar BMD. The models were adjusted for covariate variables. The middle curve exhibited a point of inflection (K) at positions 1.26.

the association between TG and lumbar BMD. (3) This study had a relatively small sample size of only 760 subjects, highlighting the need for comprehensive investigations of patients with different diseases.

Conclusions

In summary, this research evaluated the relationship between TG and lumbar BMD in OPF patients (≥50 age) and revealed a significant positive correlation with a turning point at 1.26 mmol/L. The results suggest that for the management of OPFs in patients with concurrent hypertriglyceridemia, maintaining the TG levels within the normal range and ensuring they do not fall below 1.26 mmol/L is crucial to effectively regulate TG levels without adversely affecting lumbar BMD.

	Model 3a
	Lumbar BMD
Model A[b]	
One line slope	0.015 (0.001, 0.028) 0.030
Model B[c]	
TG turning point (K)	1.26
< K	0.061 (0.024, 0.098) 0.001
> K	-0.004 (-0.023, 0.016) 0.712
Slope 2-Slope 1	-0.065 (-0.113, -0.016) 0.009
LRT[d]	0.008

Table 5. Threshold analyses examining the relationship between TG and lumbar BMD. [a]Adjusted for age, sex, BMI, magnesium; sodium; phosphorus; platelet; neutrophil; monocyte; apolipoprotein A; CR; UA; ASA; fracture category. [b]Linear analysis, P value < 0.05 indicates a linear relationship. [c]Nonlinear analysis. [d]P value < 0.05 means Model B is significantly different from Model A, which indicates a nonlinear relationship. Abbreviations: TG, triglycerides; BMD, bone mineral density; BMI, body mass index; CR, creatinine; UA, uric acid;, ASA, American Society of Anesthesiologists.

Data availability

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

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Author contributions
Peng Zhou, Lei Liu, Ke Lu, wrote the main manuscript text. Min-zhe Xu, Yao-wei Ye prepared Figs. 1, 2 and 3.Chong Li, Yi Yin prepared Tables 1, 2, 3, 4 and 5. All authors reviewed the manuscript.

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Declarations

Competing interests
The authors declare no competing interests.

Ethics approval
We received ethical approval from the Affiliated Kunshan Hospital of Jiangsu University (approval No. 2021-06-015-K01), and was compliant with the Declaration of Helsinki.

Consent to participate
Informed consent was obtained from all individual patients included in the study.

Consent to publish
Patients signed informed consent regarding publishing their data.

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