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## Research Article

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# **Triglyceride Glucose-Body Mass Index is a Reliable Indicator of Bone Mineral Density and Risk of Osteoporotic Fracture in Middle-Aged and Elderly Nondiabetic Chinese Individuals**

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**Keywords:** Triglyceride Glucose-Body Mass Index; bone mineral density; femoral neck geometry; osteoporosis; fracture; elderly

**ABSTRACT**

**Purpose:** This study aimed to investigate the relationship of triglyceride glucose-body mass index (TyG-BMI) with bone mineral density, femoral neck geometry, and risk of fracture in middle-aged and elderly Chinese individuals.

**Methods:** A total of 832 nondiabetic individuals (474 men aged  $\geq 50$  years and 358 postmenopausal women) were selected from the prospective population-based HOPE cohort. All individuals underwent dual-energy X-ray absorptiometry for assessment of bone mineral density (BMD) at the lumbar spine, femoral neck, and total hip, as well as femoral neck geometry. The 10-year probabilities of major osteoporotic fractures (MOFs) and hip fractures (HFs) were calculated. Correlations of TyG-BMI with BMD at different sites, femoral neck geometry, and risk of fractures were examined in men and women.

**Results:** Cortical thickness (CT), compression strength index (CSI), cross-sectional moment of inertia (CSMI), cross-sectional area (CSA), section modulus (SM), and 25(OH)D levels were significantly lower in women (all  $P < 0.001$ ). The presence of osteoporosis was related to age, BMI, BMD and femoral neck geometry, TyG-BMI index and TyG index, MOF and HF in both sex. TyG-BMI was positively correlated with BMD at femoral neck, lumbar spine, and total hip and with femoral neck geometry parameters in men, Similar significant association was also present in women. In men, TyG-BMI showed significant negative correlation with HF but not with MOF. In women, TyG-BMI showed significant negative correlation with both factors only after adjusting for other variable. The various geometric indices of the femoral neck were

significantly impaired in individuals with low TyG-BMI. the TyG-BMI index was found to be significantly associated with osteoporosis after adjusting for confounders.

**Conclusion:** TyG-BMI is positively associated with BMD and femoral neck geometry, and negatively associated with risk of fracture in nondiabetic middle-aged and elderly Chinese men and women.

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## INTRODUCTION

Osteoporosis is a systemic skeletal disease characterized by low bone mass and microarchitectural deterioration of bone tissue, with resulting increased bone fragility and high risk of fracture [1]. It is a major contributor to the global burden of disease, and early recognition and management will benefit both individuals and society. Bone mineral density (BMD), determined by dual-energy X-ray absorptiometry (DXA), is currently widely used to assess the quality of bone. However, only 50%–70% of total bone strength can be attributed to BMD. Previous research has shown that some patients with type 2 diabetes mellitus (T2DM) and obesity have high fracture risk despite having high BMD[2,3] [4,5]. Independent of BMD, bone geometry contribute to fracture risk[6-8]. Geometric parameters of the femoral neck, such as cross-sectional area (CSA), buckling ratio (BR) and section modulus (SM) [9] also describe bone strength and are independently predictive of hip fragility fracture [10-12].

Insulin resistance (IR) does not seem to have a detrimental effect on bone mass, the most important parameter for the diagnosis of osteoporosis [13,14]. Animal research suggest that insulin exerts an anabolic effect on bone and is a critical regulator of skeletal development and structural integrity [15,16]. In the Rotterdam Study, which enrolled nearly 6000 elderly men and women, higher glucose and insulin levels were associated with higher bone mass at all skeletal sites, supporting the association between increased insulin levels and high BMD [17]. Abrahamsen and colleagues [18] ,however, found no association between BMD and insulin, but this may have been due to the relatively small population studied. In addition to BMD, femoral neck

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geometry affects bone strength. Studies have reported an inverse association between femoral neck strength and IR<sup>[19-21]</sup>, but the study populations included individuals with and without diabetes. Shanbhogue et al<sup>[22]</sup> reported that hyperinsulinemia directly affects bone structure, independent of obesity, in non-diabetic postmenopausal women. A few studies have examined the relationship between insulin resistance and osteoporosis in non-diabetic patients. Francisco et al<sup>[23]</sup> conducted a research in non-diabetic postmenopausal women showed that there is a direct relationship between IR and BMD, but no association between IR and the prevalence of osteoporosis. It is possible that the relationship between IR and bone metabolism varies with sex, race, and bone mass or structure.

IR was earlier evaluated by the pancreatic suppression test, the hyperinsulinemic euglycemic clamp technique (HEGC), or the minimal model approximation of the metabolism of glucose<sup>[24-26]</sup>. but these methods are invasive, complicated, expensive, and difficult to use in the clinical setting. Meanwhile, the homeostasis model assessment-insulin resistance (HOMA-IR), which is mostly used nowadays, is limited by the absence of consensus on the reference value. Recently, the triglyceride and glucose–body mass index (TyG-BMI)—which incorporates fasting blood glucose, serum triglyceride levels, and body mass index (BMI)—has been proposed as a reliable and highly sensitive and specific alternative marker of IR<sup>[27,28]</sup>. Several studies have shown that high TyG-BMI is associated with cardiovascular events and incident nonalcoholic fatty liver disease<sup>[29,30]</sup>, and Khamseh et al. found that TyG-BMI is a reliable discriminator of liver fibrosis<sup>[31]</sup>. However, to date, no clinical studies have

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examined the association between TyG-BMI and bone metabolism. This study aimed to investigate how TyG-BMI is related to BMD, femoral neck geometry, and risk of fracture in nondiabetic Chinese middle-aged and elderly individuals.

## **PATIENTS AND METHODS**

The study population was selected from among the participants of the HOPE study, an ongoing prospective study that is enrolling individuals undergoing physical examination at the Health Management Center of Xiangya Second Hospital. The HOPE study, which aims to achieve a sample size of 5,000 over a period of 1 year, has already accumulated more than 1,800 patients. Patients are eligible for enrollment in the HOPE study if they 1) are  $\geq 40$  years old and 2) undergo DXA for BMD measurement. The exclusion criteria are 1) history of hip joint replacement or lumbar spine surgery; 2) inability to undergo DXA for any reason; 3) history of treatment with antiosteoporosis drugs; or 4) history of malignant tumor.

For the present study, we selected 832 healthy postmenopausal women and men aged  $\geq 50$  years from the HOPE cohort. We excluded patients with diabetes mellitus and individuals without data on fasting blood glucose or serum triglycerides. The medical records of the selected patients were searched to obtain details such as age, years since menopause, investigation results, height, and weight. BMI was calculated as the ratio of weight (in kilograms) and height (in meters) squared ( $\text{kg}/\text{m}^2$ ). This study was approved by the Ethics Committee of Xiangya Second Hospital, South China University, Changsha, China (approved number LYF2021015).

DXA scans were performed by an experienced physician using the Discovery Wi



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bone densitometer (S/N87556; Hologic, USA). The regions scanned were the left femoral neck, total hip, and lumbar spine. Seven hip geometric parameters were calculated: outer diameter, CSA, cortical thickness (CT), cross-sectional moment of inertia (CSMI), compression strength index (CSI), SM and BR (from BMD), and areal bone size data. Outer diameter refers to the outer diameter of the femoral neck at its midpoint. Endocortical diameter refers to the endocortical diameter of the femoral neck at the midpoint. CSA is an index of axial compression strength and reflects the resistance to loads directed along the bone axis. CSMI is a measure of the mass distribution relative to the geometric center; it reflects how effective a cross-section is at resisting bending and torsion—depending on the axis chosen for calculation. CT is an estimate of mean cortical thickness. BR is an index of bone geometric instability and reflects the resistance against compressive stress, which could lead to sudden sideways deflection of the structural member; higher BR values indicate greater instability and higher fracture risk [32-34]. CSI is a measure of the ability of the femoral neck to withstand compressive load in the axial dimension. SM, computed as CSMI divided by the distance from the bone edge to the centroid, describes femoral neck bending strength. A China-specific fracture risk assessment tool (FRAX) algorithm (which included the femoral neck BMD T-score) was used to determine the 10-year probability of major osteoporotic fractures (MOFs) and hip fractures (HFs).

Blood samples were obtained after an overnight fast of at least 8 hours. Fasting blood glucose, serum triglycerides, serum total cholesterol, and serum high-density lipoprotein cholesterol were measured using an ADVIA 1650 Chemistry Analyzer

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(Siemens, Washington, DC, USA) in 2007, and a Hitachi 7600 Automatic Analyzer (Hitachi, Tokyo, Japan) from 2008 to 2010. Serum levels of total 25-hydroxyvitamin D (25OHD) was measured by an automated chemiluminescence system. TyG-BMI was calculated using the formula <sup>[35]</sup>.  $TyG-BMI = \ln[\text{fasting glucose}(\text{mg/dL}) \times \text{triglycerides}(\text{mg/dL})/2] \times \text{BMI}$ .

### **Statistical Analysis**

Continuous data were assessed for normality and analyzed using the independent samples *t*-test or the Mann–Whitney *U* test, as appropriate. Pearson or Spearman correlation was used to examine associations between TyG-BMI and BMD, femoral neck geometry, and risk of fracture. Participants were stratified by sex to examine sex-specific associations. Multivariable linear regression analysis was used to explore associations between TyG-BMI and femoral neck parameters (bone density and femoral neck geometry) in the two sexes. Multivariable logistic regression analysis was used to explore associations between TyG-BMI and osteoporosis. All analyses were performed using SPSS 26 (IBM Corp., Armonk, NY, USA). Statistical significance was at  $P < 0.05$ .

## **RESULTS**

### **Clinical Characteristics of the Study Population**

Characteristics of the 832 individuals (474 men, 358 women) are summarized in Table S1 and Table 1. Mean age was comparable between men and women ( $59.0 \pm 7.95$  years vs.  $59.6 \pm 7.72$  years,  $P = 0.126$ ). Mean TyG-BMI was significantly higher in men than in women ( $219.6 \pm 32.5$  vs.  $202.5 \pm 29.8$ ,  $P < 0.001$ ). The prevalence of osteoporosis (as diagnosed by the BMD T-score) was higher in women than in men

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(20.1% vs. 9.5%,  $p < 0.05$ ). Other detailed baseline characteristics are presented in Additional file 1: Table S1. Compared to non-osteoporotic group, the presence of osteoporosis was related to age, BMI, BMD and femoral neck geometry, TyG-BMI index and TyG index, MOF and HF in both sex (Table 1).

### **Association of TyG-BMI with BMD**

Figure 1 shows the correlation of TyG-BMI with BMD at different sites. In men, TyG-BMI was positively correlated with femoral neck-BMD ( $r = 0.236$ ,  $P < 0.001$ ), total hip-BMD ( $r = 0.249$ ,  $P < 0.001$ ), and lumbar spine-BMD ( $r = 0.145$ ,  $P = 0.002$ ). Similarly, in women, TyG-BMI index was positively correlated with femoral neck-BMD ( $r = 0.186$ ,  $P < 0.001$ ), total hip-BMD ( $r = 0.259$ ,  $P < 0.001$ ), and lumbar spine-BMD ( $r = 0.133$ ,  $P = 0.013$ ). In both sexes, the association persisted even after adjusting for age, smoking, drinking, and history of previous hip fracture or parental hip fracture (Table 3).

### **Association of TyG-BMI with Femoral Neck Geometry and Risk of Fracture**

In unadjusted analysis (Table 2), TyG-BMI was positively correlated with femoral neck CSA, CSMI, SM, and CT in both men and women (all  $P < 0.001$ ), but negatively correlated with BR and CSI. In both sexes, the associations remained statistically significant even after adjusting for age, smoking, drinking, and history of previous hip fracture or parental hip fracture (Table 3). In men, TyG-BMI was significantly correlated to HF but not to MOF; in women, TyG-BMI was not significantly correlated with either of the two factors ( $P > 0.05$ ). However, in women, after adjusting for age, smoking, drinking, and history of previous hip fracture and parental hip fracture, TyG-

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BMI was significantly associated with MOF and HF; in men, the TyG-BMI remained significantly associated with HF.

### **Multiple Linear Regression Analysis of Association between TyG-BMI and BMD and Bone Geometric Parameters**

Linear regression analysis showed that TyG-BMI was a significant independent predictor of BMD, SM, CSA, CSI, and BR. The standardized regression coefficients of TyG-BMI in men (Table 3a) and women (Table 3b), respectively, were 0.234 ( $P < 0.001$ ) and 0.279 ( $P < 0.001$ ) for femoral neck BMD, 0.176 ( $P < 0.001$ ) and 0.192 ( $P < 0.001$ ) for total hip BMD, 0.238 ( $P < 0.001$ ) and 0.283 ( $P < 0.001$ ) for CSA, 0.212 ( $P < 0.001$ ) and 0.228 ( $p < 0.001$ ) for SM, and  $-0.202$  ( $P < 0.001$ ) and 0.282 ( $P < 0.001$ ) for BR.

### **Distributions of the TyG-BMI index according to the bone health status.**

In the evaluation of the relationship between TyG-BMI index and the bone health status, patients with osteoporosis had a lower TyG-BMI index ( $P$  for trend = 0.006) compared to the others, showing a dose–response manner (Figure. 2).

### **Multivariable logistic regression analyses between possible predictors and osteoporosis.**

In the multivariable logistic regression analyses, the TyG-BMI index was found to be significantly associated with osteoporosis (adjusted odds ratio [aOR] = 1.019; 95% confidence interval [CI] = 1.01–1.028) after adjusting for confounders. Age (aOR = 0.919; 95% CI = 0.892–0.947) and Sex, female (aOR = 0.489; 95% CI = 0.266–0.889) were also related to osteoporosis (Table 4).

## **DISCUSSION**

This is the first study to investigate the association of TyG-BMI with bone mass and femoral neck geometry in healthy, nondiabetic, middle-age and elderly individuals. The proximal femur, hip, and the lumbar spine were examined, as these are anatomical sites at high risk of osteoporotic fractures. As measures of bone strength, we used areal BMD (aBMD) and femoral geometry. TyG-BMI, which combines serum triglycerides, fasting plasma glucose, and obesity status, is considered more reliable than TyG for the identification of IR. It is a less expensive and more reliable marker of IR than traditional markers like HOMA-IR [36,37].

We demonstrated that higher aBMD was associated with higher bone strength and lower fracture risk at all sites, with the association being significantly stronger in men than in postmenopausal women. The sex differences in these parameters may explain the higher incidence of fragility fractures in women. It also implies that sex-dependent femoral neck geometry contributes significantly to the ability to withstand stress.

The relationship between IR and BMD has been studied in different populations but the results have been mixed. Consistent with Riggs et al. [38], we found that higher TyG-BMI was associated with greater aBMD at both weight-bearing and non-weight-bearing skeletal sites, TyG-BMI index was significantly associated with osteoporosis. Previous studies have reported association between bone metabolism and HOMA-IR, another surrogate marker of IR. Further, greater IR was found to be associated with higher BMD [39,40]. In a study of Caucasian non-diabetic women from the Study of Women's Health Across the Nation (SWAN) found that higher IR is associated with greater volumetric BMD and generally favorable bone microarchitecture at non-

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weight-bearing distal radius and weight-bearing distal tibia, independent of body weight<sup>[20]</sup>. This effect of hyperinsulinism on BMD may be because insulin exerts peripheral osteogenic effects via stimulation of osteoblasts or inhibition of osteoclasts. All these research results suggest that TyG-BMI index is a protective factor for osteoporosis. However, Shin et al.<sup>[41]</sup> reported an inverse relationship between HOMA-IR and aBMD in a population-based study of young South Korean men (mean age, 49.9 years) suggesting that IR is a negative predictor of bone health. Our study population differs from that of Shin et al.<sup>[41]</sup> in several aspects: our study participants were Chinese, older (mean age, 60.3 years) and, importantly, nondiabetic. It is currently unknown whether the effects of IR or hyperinsulinemia on bone are age-, sex- or race-specific. The inclusion of patients with diabetes in Shin et al.<sup>[41]</sup> may have confounded their results as HOMA-IR is unreliable in patients on antidiabetic medications; further, chronic hyperglycemia and/or antidiabetic medications may affect skeletal microarchitecture. Thus, comparison of their findings with ours is difficult.

In this study we also investigated the association between TyG-BMI and femoral neck geometry. A recent study showed that several conditions associated with altered bone metabolism (for example, sarcopenia) result in poor femoral neck geometry, suggesting that these indices on DXA scans may be a good indicator of bone health<sup>[42]</sup>. Consistent with a previous Chinese study<sup>[43]</sup>, we found that CSA, CT, SM, CSMI, and CSI decrease with age, whereas BR increases with age. These results imply the decrease in CSA, CT, SM, CSMI, and CSI and increase in BR might contribute to fragility fractures of the femoral neck in old age. Further, CSA, CT, SM, CSMI, and CSI were

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lower, and BR higher, in women than in men, which may explain the greater vulnerability of the femoral neck in the former.

There is a paucity of data describing the relationships between IR and femoral neck geometry. In the present study, TyG-BMI was positively associated with femoral neck CSA and SM, but negatively associated with BR; the relationships remained statistically significant even after controlling for age and previous fracture, suggesting that IR contributed to favorable femoral neck geometry. A possible explanation for this relationship is that insulin has an anabolic effect on bone, stimulating osteoblast growth and proliferation on periosteal surfaces and thus increasing SM and CSA. Overall, the results suggest that TyG-BMI has a positive effect on bone geometry in middle-aged and elderly Chinese individuals. Contrary to our findings, an inverse association between IR and bone size has been demonstrated in nondiabetic postmenopausal Caucasian women <sup>[22]</sup>. In Korean men and women, with and without diabetes, HOMA-IR and fasting insulin levels were found to be inversely associated with composite indices of femoral neck strength<sup>[44]</sup>. The primary difference between our study and the studies mentioned above is in the populations enrolled, implying that differences in sex, age, diabetes status, and race affect the relationship between IR and bone structure.

This study has some limitations. First, this was a retrospective study, so we cannot infer that IR leads to high bone strength; that will have to be clarified in longitudinal studies. Second, serum levels of hormones that affect bone metabolism (e.g., estrogen, androgen, and pituitary gonadotropin) were not evaluated in our study. Third, we did

not use the HEGC technique and HOMA-IR for measuring IR, these methods, although accurate and popular, are time-consuming and costly and therefore not suitable for application in large samples. TyG-BMI is a reliable and highly sensitive alternative to HEGC [27].

In summary, TyG-BMI may be a reliable indicator of favorable bone density and strength in healthy, nondiabetic postmenopausal women and men and could be useful in the clinic to evaluate and predict the risk of osteoporosis. More mechanistic studies, both preclinical and clinical, are needed to better understand the effect of IR on bone and to clarify whether insulin resistance-related changes affect fracture risk.

**ABBREVIATIONS:**

AGE, glycation end product

BMD, bone mineral density

BMI, body mass index

BR, buckling ratio

CSA, cross-sectional area

CSI, compression strength index

CSMI, cross-sectional moment of inertia

CT, cortical thickness

DXA, dual-energy X-ray absorptiometry

HEGC technique, hyperinsulinemic euglycemic clamp technique

HFs, hip fractures (HFs)

HOMA-IR, homeostatic model assessment for insulin resistance



IR, insulin resistance

MOFs, major osteoporotic fractures

SM, section modulus

T2DM, type 2 diabetes mellitus

TyG-BMI index, triglyceride and glucose–body mass index

### **Declarations:**

### **Consent for publication**

Not applicable

### **Availability of data and materials**

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

### **Competing interests**

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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## Author Contributions

The study conception and design were performed by SF and LH. Data collection and analysis were performed by WZ, XL, LY, YY, CR, WQ. Data verification and the first draft of the manuscript was written by WZ, DN, QX, YC. OY and CR were responsible for statistical analysis. All authors approved the final manuscript and taking final responsibility for the paper.

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**Table 1** Baseline characteristics of osteoporosis and non-osteoporosis group

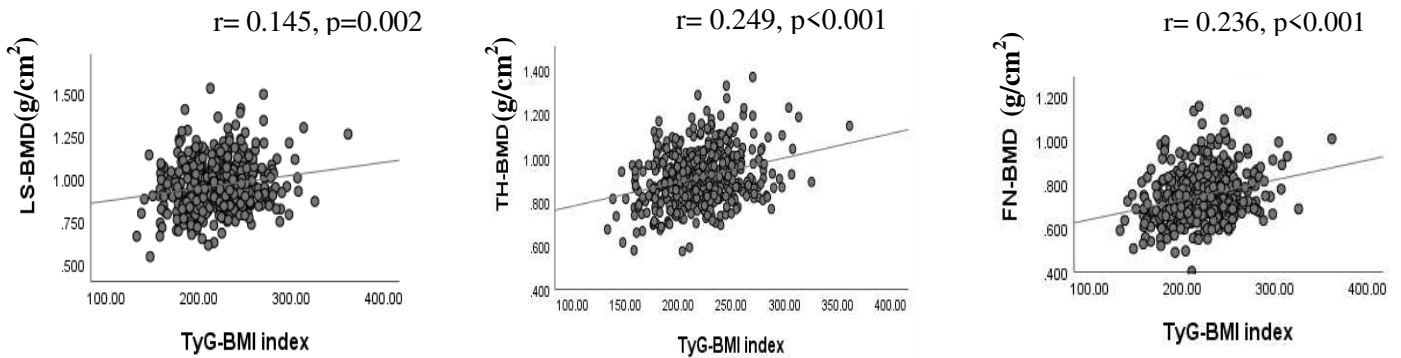
	Men		Women	
	Osteoporosis	Non-osteoporosis	Osteoporosis	Non-osteoporosis
Age (years)	62.0±1.00*	59.0±0.00	65.0±1.00*	59.0±0.00
Height(cm)	164.3±0.90*	167.7±0.30	152.8±0.80*	156.5±0.30
Weight (kg)	61.8±1.20*	70.7±0.40	53.1±0.80*	57.9±0.50
BMI(kg/m <sup>2</sup> )	22.9±0.41*	25.1±0.13	22.7±0.30*	23.6±0.18
Cholesterol(mmol/L)	4.87±0.13	4.91±±0.05	5.08±0.12*	5.36±0.06
Triglyceride(mmol/l)	1.57±0.10	1.90±0.07	1.37±0.09	1.57±0.06
HDL(mmol/l)	1.27±0.04	1.23±0.02	1.48±0.04	1.50±0.02
LDL(mmol/l)	3.10±0.12	3.08±0.04	3.20±0.12	3.37±0.05
FBG(mmol/l)	5.22±0.14	5.33±0.05	5.24±0.09	5.30±0.06
25(OH)D(nmol/l)	45±2.00	46±1.00	41.0±2.00	43.0±1.00
P(mmol/L)	0.86±0.03	0.91±0.01	1.04±0.03	1.04±0.02
Ca(mmol/l)	2.24±0.03	2.25±0.01	2.28±0.03	2.26±0.01
FN-BMD(g/cm <sup>2</sup> )	0.58±0.01*	0.76±0.01	0.54±0.01*	0.69±0.01
LS-BMD(g/cm <sup>2</sup> )	0.81±0.02*	0.98±0.01	0.68±0.01*	0.88±0.01
TH-BMD(g/cm <sup>2</sup> )	0.74±0.01*	0.93±0.01	0.67±0.01*	0.83±0.01
FN-CT(mm)	0.11±0.00*	0.15±0.00	0.10±0.00*	.13±0.00
FN-SM(cm <sup>3</sup> )	1.32±0.03*	1.69±0.02	0.94±0.02*	1.17±0.01
FN-CSMI(cm <sup>4</sup> )	2.39±0.07*	3.05±0.04	1.48±0.04*	1.86±0.03
FN-CSI(g·kg <sup>-1</sup> ·m <sup>-1</sup> )	3.43±0.08*	3.90±0.03	3.23±0.05*	3.77±0.04
FN-CSA(cm <sup>2</sup> )	1.99±0.03*	2.60±0.02	1.62±0.03*	2.06±0.01
FN-BR	16.6±0.29*	12.5±0.08	15.7±0.31*	12.3±0.12
MOF (%)	4.50±0.30*	2.50±0.10	6.10±0.30*	3.60±0.10
HF (%)	2.60±0.30*	0.60±0.00	2.70±0.20*	0.70±0.00
TyG index	8.69±0.07	8.81±0.03	8.54±0.06	8.66±0.03
TyG-BMI index	199.1±4.27*	221.7±1.56	193.8±2.98*	205.2±1.89
Smoke, %(n)	46.7(21)	34.8(149)	1.1(4)	0(0)
Drink, %(n)	84.4(38)	18.9(66)	0.4(1)	0(0)
Previous fracture,(n)	8.9(4)	6.5(28)	15.3(12)	13(35)
Parental hip fracture,% (n)	6.7(3) *	21.8 (54)	12.5(10)	11.5(32)

BMI, body mass index; FN: femoral neck; TH:total hip; LS:lumber spine;BMD: body mineral density; CT: cortical thickness; CSMI: Cross sectional moment of inertia; CSI: compression strength index; CSA: Cross sectional area; SM: Section modulus ;BR: buckling ratio ; CT: Cortical

thickness ; MOF: major osteoporosis fracture; HF: hip fracture; HDL-C high density lipoprotein cholesterol, LDL-C low density lipoprotein cholesterol, FPG fasting plasma glucose; TyG triglyceride glucose index, TyG-BMI combined TyG and BMI.

\*:p<0.05

### Men



### Postmenopausal women

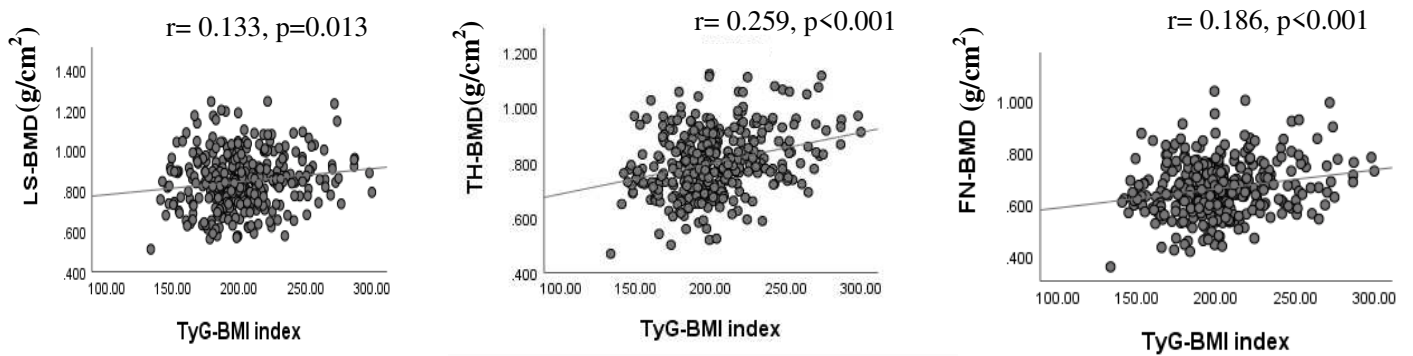


Figure 1. Correlations of serum TyG-BMI level with BMD.

FN: femoral neck; TH:total hip; LS:lumber spine;BMD: body mineral density;

TyG triglyceride glucose index, TyG-BMI combined TyG and BMI.

**Table2** Correlations of triglyceride glucose-body mass index and bone strength and risk of fracture

	men	women
	r	r
FN-CSMI(cm <sup>4</sup> )	0.144**	0.129*
FN-CSI(g·kg <sup>-1</sup> ·m <sup>-1</sup> )	-0.418**	-0.408**
FN-CSA(cm <sup>2</sup> )	0.219**	0.190**
FN-BR	-0.206**	-0.119*
FN-CT(mm)	0.237**	0.185**
FN-SM(cm <sup>3</sup> )	0.177**	0.158**
MOF	-0.076	0.05
HF	-0.178**	-0.064

FN: femoral neck; CT: cortical thickness; CSMI: Cross sectional moment of inertia; CSI: compression strength index; CSA: Cross sectional area; SM: Section modulus ;BR: buckling ratio; TyG-BMI combined TyG and BMI; MOF:major osteoporotic fracture;HF:hip fracture



**Table3a** Lineal regression analysis between the TyG-BMI index and the densitometry parameters.

	men			
	unadjusted	Model1 $\beta$	Model2 $\beta$	Model3 $\beta$
FN-CSI( $\text{g}\cdot\text{kg}^{-1}\cdot\text{m}^{-1}$ )	-0.401**	-0.414**	-0.426**	-0.426**
FN-CSMI( $\text{cm}^4$ )	0.213**	0.191**	0.182**	0.182**
FN-SM( $\text{cm}^3$ )	0.238**	0.212**	0.205**	0.204**
FN-CT(mm)	0.263**	0.238**	0.230**	0.231**
FN-BR	-0.227**	-0.202**	-0.194**	-0.195**
FN-CSA( $\text{cm}^2$ )	0.2693**	0.238**	0.229**	0.229**
FN-BMD( $\text{g}/\text{cm}^2$ )	0.265**	0.234**	0.223**	0.224**
LS-BMD( $\text{g}/\text{cm}^2$ )	0.173**	0.176**	0.185**	0.185**
TH-BMD( $\text{g}/\text{cm}^2$ )	0.293**	0.275**	0.27**	0.271**
MOF	-0.067	-0.031	-0.055	-0.108
HF	-0.125	-0.078*	-0.116*	-0.141*

Model 1 adjusted age; model2 :adjusted age, smoke, drink; model3 :adjusted age, smoke, drink, previous fracture, parental hip fracture.

FN: femoral neck; TH: total hip; LS:lumber spine;BMD: body mineral density; CSI: compression strength index; CSMI: Cross sectional moment of inertia ; SM: Section modulus ; CT: Cortical thickness ; BR: buckling ratio ; CSA: Cross sectional area; MOF:major osteoporotic fracture;HF:hip fracture;TyG triglyceride glucose index, TyG-BMI combined TyG and BMI,

\*\* :  $p < 0.001$ ; \*: $p < 0.05$ .

**Table3b** Lineal regression analysis between the TyG-BMI index and the densitometry parameters.

	women			
	unadjusted	Model1 $\beta$	Model2 $\beta$	Model3 $\beta$
FN-CSI(g·kg <sup>-1</sup> ·m <sup>-1</sup> )	-0.409**	-0.367**	-0.367**	-0.368**
FN-CSMI(cm <sup>4</sup> )	0.147*	0.194**	0.194**	0.194**
FN-SM(cm <sup>3</sup> )	0.180**	0.228**	0.228**	0.227**
FN-CT(mm)	0.213**	0.342**	0.341**	0.342**
FN-BR	-0.167**	0.283**	0.283**	0.282**
FN-CSA(cm <sup>2</sup> )	0.2203**	0.283**	0.283**	0.282**
FN-BMD(g/cm <sup>2</sup> )	0.214**	0.279**	0.279**	0.279**
LS-BMD(g/cm <sup>2</sup> )	0.142**	0.192**	0.193**	0.192**
TH-BMD(g/cm <sup>2</sup> )	0.292**	0.411**	0.41**	0.415**
MOF	0.015	-0.148*	-0.148*	-0.219*
	-0.089	-0.293**	-0.293**	-0.309**

Model 1 adjusted age; model2 :adjusted age, smoke, drink; model3 :adjusted age, smoke, drink, previous fracture, parental hip fracture.

FN: femoral neck; TH: total hip; LS:lumber spine;BMD: body mineral density; CSI: compression strength index; CSMI: Cross sectional moment of inertia ; SM: Section modulus ; CT: Cortical thickness ; BR: buckling ratio ; CSA: Cross sectional area; MOF:major osteoporotic fracture;HF:hip fracture;TyG triglyceride glucose index, TyG-BMI combined TyG and BMI,

\*\* : p<0.001; \*:p<0.05.

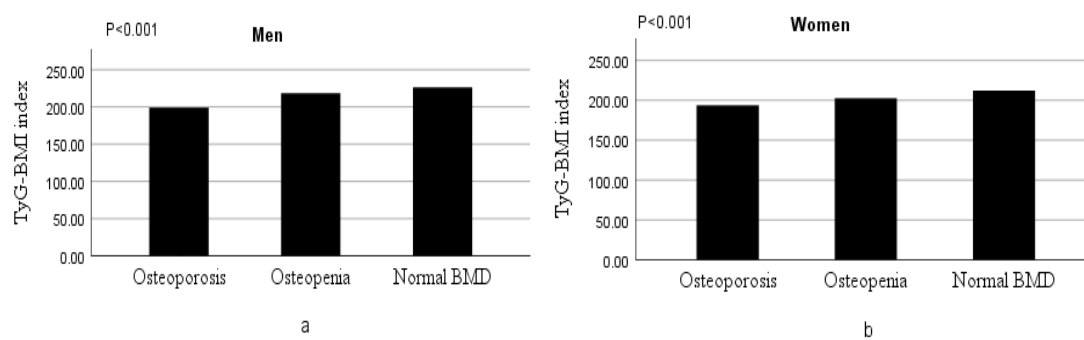


Figure2 Distributions of the TyG-BMI index according to the bone health status.

**Table4** Multivariable logistic regression analyses between possible predictors and osteoporosis

	Unadjusted OR (95% CI)	P-value	Adjusted OR (95% CI)	P-value
Age	0.929(0.907,0.950)	<0.001	0.919(0.892,0.947)	<0.001
Sex, female	0.393(0.263,0.587)	<0.001	0.486(0.266,0.889)	0.019
History of Parental hip fracture	0.823(0.434,1.559)	0.550	0.872(0.414,1.836)	0.719
Current Smoker	0.784 (0.473,1.730)	0.346	0.353(0.176,0.709)	0.003
Current Drinker	0.389 (0.176,0.860)	0.020	1.588(0.608,4.145)	0.345
25(OH)D	1.011(0.996,1.027)	0.142	1.018(1.002,1.034)	0.026
TyG-BMI index	1.022(1.014,1.029)	<0.001	1.019(1.010,1.028)	<0.001

Adjusted with age, sex, 25(OH)D, current smoker, current drinker.

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [supplemental1.docx](#)