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Prevalence and Risk Factors of Osteoporosis in a Chinese Population: A Cross-Sectional Study in Xi'an, Shaanxi Province, China

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Conflict of interest: None declared

Background: Osteoporosis is a systemic chronic disease characterized by bone mineral density (BMD) reduction. This study aimed to assess the prevalence of osteoporosis and fracture risks in northwestern China and investigate the related anthropometric risk factors.


Material/Methods: Between July 2022 and August 2022, 1429 participants (1295 females, 134 males) with measured BMD were recruited to participate in this cross-sectional study. Data on height, weight, and T score were collected. Spearman's correlation and multiple linear regression analysis were used to investigate the relationships between various demographic factors and BMD and the 10-year risk of major osteoporotic fracture (MO) and hip fracture (HP).

Results: The overall prevalence of osteoporosis in northwest China was 42.34%, with 44.56% in females and 20.90% in males. Age negatively affects females' T scores ($r=-0.304$, $P<0.05$), and height positively influences both sexes' T scores ($r=0.059$, $P<0.05$). Age ($r=0.148$, $P<0.05$) and height were positive predictors of MO ($r=0.027$, $P<0.05$), while weight was a negative predictor ($r=-0.035$, $P<0.05$). The conclusion for HP was consistent with that of MO, except for the T score, which was a positive predictor of HP ($r=0.014$, $P<0.05$).

Conclusions: The prevalence of osteoporosis in northeast China is high. The association between anthropometric parameters and osteoporosis in adults in northwest China is different between sexes.

Keywords: Osteoporosis • Bone Density • Fractures, Bone • China

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Background

Osteoporosis is a systemic disease characterized by bone mineral density (BMD) reduction, bone fragility, and skeletal tissue deterioration [1]. It can lead to pain, disability, a decline in quality of life, and even shortened life expectancy [2]. It is estimated that approximately 200 million people worldwide suffer from osteoporosis [3], and the prevalence of this disease increases with age and is higher in females than in males [4]. A research report predicted the number of people at high risk of osteoporosis fractures will rise from 158 million currently to 319 million by 2040 [5]. In China, the morbidity rate of osteoporosis has increased for decades, affecting approximately one-third of people aged 50 years and older [4]. Currently, an estimated 10.9 million men and 49.3 million women in China suffer from osteoporosis [6].

Bone mineral density (BMD) is an important indicator of bone strength, and its reduction is reliable for diagnosing and evaluating osteoporosis [7]. The T score and the Z-score are used to express the condition of BMD, with a T score -2.5 or below the score indicating osteoporosis, a T score between -2.5 and -1 indicating osteopenia, and a T score of -1 or above indicating normal bone mass [8]. Dual-energy X-ray absorptiometry (DXA) is considered the criterion standard for diagnosis of osteoporosis [9], but it is expensive and involves some exposure to radiation, making it less suitable for screening for changes in bone density [10]. Studies have shown that radius quantitative ultrasound (QUS) is a more practical and non-radiational tool to assess osteoporosis, providing a reference for improved fracture risk assessment [11].

Various non-modifiable, modifiable, and lifestyle factors affect osteoporosis [12]. Non-modifiable factors, such as genes, advanced age, female sex, and familial predisposition, play a significant role in the majority of the risk of osteoporosis [5]. Some studies have confirmed that age, sex, weight, and BMI are important predictors of osteoporosis, but the exact association has not been fully determined in Chinese people [13].

We conducted a cross-sectional study following 1429 participants to assess the prevalence of osteoporosis using QUS and calculated their fracture risks using FRAX tool in a population of both sexes in Xi'an, Shaanxi Province, China. We investigated the effects of age, sex, weight, height, and BMI on BMD and fracture risks through multiple linear regression analysis to provide a general description of osteoporosis in the population of northwest China. This study aimed to determine the characteristics of osteoporosis and fracture risks in northwest China, to assess the sex differences in osteoporosis in the population, and to draw relevant conclusions. We also studied the association of age, BMI, and other factors with osteoporosis and fracture risks.

Material and Methods

Ethics Approval

The study protocol was approved by the Ethics Committee of the Second Affiliated Hospital of Xi'an Jiaotong University (No. 2023264), and written informed consent was obtained from each participant.

Study Design and Population

This was a cross-sectional study. A total of 1295 female and 134 male participants aged 30 years or older who had undergone routine physical check-ups were recruited from our hospital in Xi'an, Shaanxi province of China between July 2022 and August 2022. Each participant underwent anthropometric and wrist BMD measurements. Exclusion criteria were metabolic bone disease history, history of diseases affecting body composition or weights, and lack of data for necessary items or written informed consent could not be obtained.

Data Collection

A general anthropometric measurement was performed for all participants. Weight and height were measured wearing thin clothes and removing shoes. BMI was calculated as weight (kg) divided by height squared (m^2).

The BMD of the right wrist was measured using a dry quantitative ultrasound device (BMD-A3, Pinyuan Tec., Xuzhou, China). The instruments were calibrated daily according to the operating instruction before measurement and each participant was measured twice on the right wrist by a well-trained doctor, and the mean value was used for further analysis. The output parameters include speed of sound (SOS, m/s), T score, and Z-score. T scores and Z-scores of BMD were calculated using data on healthy Chinese as a reference.

The World Health Organization (WHO) introduced the fracture risk assessment tool (FRAX) in 2008 to estimate the absolute risk of osteoporotic fractures in a certain range of patients [14], using the interaction of risk factors such as height, weight, age, sex, family, and personal history [15]. The FRAX score was used to determine the participants' 10-year risk of major osteoporotic fracture and hip fracture. It was calculated using sex, age, weight (kg), and height (cm) with the FRAX tool online calculator of the Center for Metabolic Bone Diseases, University of Sheffield, UK (<https://www.sheffield.ac.uk/FRAX/index.aspx>).

Definition

A diagnosis of osteoporosis is made based on the WHO definition. According to the WHO, the T score represents the number

Table 1. Baseline characteristics of overall populations.

Clinical variables	Overall	Female	Male
Numbers	1429	1295	134
Height (cm)	160.36±6.04	159.46±5.23	169.06±6.44
Weight (kg)	60.22±8.65	59.30±7.87	69.10±10.67
BMI (kg/m²), n (%)	23.37±2.72	23.29±2.68	24.10±2.93
<25 (normal)	1050 (73.48)	967 (74.67)	83 (61.94)
25-30 (oveweight)	360 (25.19)	314 (24.25)	46 (34.33)
>30 (obese)	19 (1.33)	14 (1.08)	5 (3.73)
Age (years), n (%)			
35-44	25 (1.75)	18 (1.39)	7 (5.22)
45-54	127 (8.89)	118 (9.11)	9 (6.72)
55-64	693 (48.50)	641 (49.50)	52 (38.81)
65-74	525 (36.74)	478 (36.91)	47 (35.07)
74-86	59 (4.12)	40 (3.09)	19 (14.18)
BMD, n (%)			
Normal	365 (25.54)	306 (23.63)	59 (44.03)
Osteopenia	459 (32.12)	412 (31.81)	47 (35.07)
Osteoporosis	605 (42.34)	577 (44.56)	28 (20.90)
Fracture risks, %			
MO	3.57±1.21	3.70±1.17	2.21±0.55
HP	1.02±0.79	1.05±0.81	0.72±0.53

BMI – body mass index; BMD – bone mineral density; MO – 10-year risk of major osteoporotic fracture; HP – 10-year risk of hip fracture.

of standard deviations (SD) below or above the average BMD. Participants were classified as normal (T score > -1.0), having osteopenia (-2.5 < T score < -1.0), and having osteoporosis (T score < -2.5) [16].

Statistical Analysis

Statistical analyses were performed using the SPSS version 26 (SPSS, Inc., Chicago, IL, USA). Continuous variables are expressed as mean±SD and categorical data are presented as percentages. We used unpaired and paired *t* tests to compare linear variables, while dichotomous variables were assessed using a chi-squared test. Spearman regression analyses and univariate and multiple linear regression analysis were performed to assess the association between T score and the following variables: sex, age, weight, height, and BMI. In addition, univariate and multiple linear regression analysis were used to evaluate the relationship between FRAX score and the

following variables: sex, age, weight, height, and BMI. A *P* value <0.05 was considered statistically significant.

Results

Baseline Characteristics of Overall Population

The baseline characteristics of overall population are presented in **Table 1**. A total of 1429 participants (1295 women and 134 men, mean BMI 23.37±2.72 kg/m²) were included in this cross-sectional study. According to **Table 1**, there was no significant difference in the mean BMI between the sexes. The prevalence of osteoporosis among all participants was 42.34%, with a higher prevalence in females (44.56%) than in males (20.90%).

Table 2. Spearman's rank correlation coefficient for T score.

Variable	Overall		Female		Male	
	Coefficient	P	Coefficient	P	Coefficient	P
Gender	-0.165	<0.001	–	–	–	–
Age	-0.298	<0.001	-0.304	<0.001	-0.430	<0.001
Height	0.186	<0.001	0.143	<0.001	0.045	0.606
Weight	0.126	<0.001	0.088	<0.01	0.073	0.402
BMI	0.036	0.180	0.022	0.428	0.022	0.803

Table 3. Linear regression analysis for overall T score.

Variable	Univariate linear regression		Multivariate linear regression	
	β (95% CI)	P	β (95% CI)	P
Gender	-1.027 (-1.359, -0.695)	<0.001	-0.865 (-1.222, -0.509)	<0.001
Age	-0.083 (-0.096, -0.070)	<0.001	-0.083 (-0.095, -0.070)	<0.001
Height	0.059 (0.043, 0.075)	<0.001	0.021 (0.001, 0.041)	0.039
Weight	0.029 (0.018, 0.041)	<0.001	0.007 (-0.006, 0.021)	0.264
BMI	0.028 (-0.008, 0.065)	0.122	–	–

The fracture risks were also assessed in the study population using sex, age, weight (kg) and height (cm) with the FRAX tool. The 10-year risk of major osteoporotic fracture was (3.57±1.21)% for the total population and (1.02±0.79)% for hip fracture. In females, the 10-year risk of major osteoporotic fracture was (3.70±1.17)% and (1.05±0.81)% for hip fracture. Conversely, in males, the 10-year risk of major osteoporotic fracture was (2.21±0.55)% and (0.72±0.53)% for hip fracture (Table 1).

Spearman's Correlation Analysis for the Association Between Sex, Age, Weight, Height, BMI and T Score

Based on the results shown in Table 2, for the overall population, it is evident that sex, age, height, and weight were significantly associated with T scores (P<0.05), while there was no correlation between BMI and T score (P>0.05). Spearman's correlation analysis revealed a positive correlation between height, weight, and T score, indicating that individuals with higher heights and weights tend to have higher T scores. Conversely, a negative correlation was observed between age and T score, indicating that older individuals tend to have lower T scores.

Further analysis of the subgroups by sex revealed intriguing findings. Specifically, in females, spearman's correlation analysis showed that age, height, and weight were significantly associated with T score (P<0.05), indicating that these variables play a crucial role in determining T scores in females. In contrast, in males, only age was found to be significantly

associated with T score (P<0.05), while height and weight did not have a significant impact. This suggests that the determinants of T score differ between males and females, and further exploration is required to understand the underlying factors that influence T scores in each sex (Table 2).

Association Between Sex, Age, Weight, Height, BMI, and T Score

According to the results of our statistical analysis, as demonstrated in Table 3, the univariate linear regression analysis revealed that sex, age, height, and weight were all associated with the T score in the overall study population (P<0.001), while there was no significant correlation between BMI and T score (P>0.05). Moreover, the multivariate linear regression analysis showed that sex, age, and height remained significant predictors of T scores, even after controlling for the effects of the other variables. However, the relationship between body weight and the T score was no longer significant in the multivariate model (Table 3).

Additionally, separate univariate and multivariate linear regression analyses on females were conducted (Table 4). In this subgroup analysis, age, height, and weight were found to be significant predictors of T scores (P<0.001), whereas BMI were not significantly correlated with T scores (P>0.05). The findings regarding age and height were further supported by the multiple linear regression analysis, which showed that age was

Table 4. Linear regression analysis for the female T score.

Variable	Univariate linear regression		Multivariate linear regression	
	β (95% CI)	P	β (95% CI)	P
Age	-0.088 (-0.102, -0.074)	<0.001	-0.084 (-0.098, -0.070)	<0.001
Height	0.052 (0.032, 0.071)	<0.001	0.024 (0.003, 0.046)	0.027
Weight	0.023 (0.010, 0.036)	<0.01	0.009 (-0.006, 0.021)	0.209
BMI	0.020 (-0.018, 0.058)	0.307	–	–

Table 5. Multivariate linear regression analysis for overall fracture risks.

Variable	MO		HP	
	β (95% CI)	P	β (95% CI)	P
Gender	1.671 (1.592, 1.749)	<0.001	0.409 (-8.047, -6.600)	<0.001
Age	0.148 (0.145, 0.151)	<0.001	0.094 (0.091, 0.097)	<0.001
Height	0.023 (0.018, 0.027)	<0.001	0.024 (0.020, 0.028)	<0.001
Weight	-0.035 (-0.038, 0.032)	<0.001	-0.037 (-0.039, -0.034)	<0.001
T-score	0.007 (-0.004, 0.018)	0.212	0.014 (0.003, 0.025)	0.011

MO – 10-year risk of major osteoporotic fracture; HP – 10-year risk of hip fracture.

Table 6. Multivariate linear regression analysis for female fracture risks.

Variable	MO		HP	
	β (95% CI)	P	β (95% CI)	P
Age	0.165 (0.163, 0.167)	<0.001	0.101 (0.098, 0.104)	<0.001
Height	0.027 (0.024, 0.030)	<0.001	0.026 (0.022, 0.030)	<0.001
Weight	-0.039 (-0.041, -0.037)	<0.001	-0.040 (-0.042, -0.037)	<0.001
T-score	0.011 (0.004, 0.018)	0.004	0.017 (0.006, 0.028)	0.002

MO – 10-year risk of major osteoporotic fracture; HP – 10-year risk of hip fracture.

negatively correlated with T scores ($P<0.001$) and height was positively correlated with T scores ($P<0.05$) (Table 4).

Association Between Sex, Age, Weight, Height, and T Score and Fracture Risks

Multiple linear regression analysis was conducted to investigate the relationships between various demographic factors and the 10-year risk of major osteoporotic fracture (MO) and hip fracture (HP). The results showed that sex, age, weight, and height were significantly related to MO in the total population. In particular, age and height were positively correlated with MO, while weight was negatively correlated with MO (Table 5). Furthermore, our analysis revealed that sex, age, weight, height, and T score were significantly associated with HP in the total population. In particular, age, height, and T score were positively correlated with HP, while weight was negatively correlated with HP (Table 5).

After our analysis of the total population, we then carried out subgroup analyses for females. According to Table 6, in females, age, height, weight, and T score were all significantly associated with both MO and HP. Specifically, age, height, and T score were positively correlated with both MO and HP, while weight was negatively correlated with both MO and HP (Table 6).

Discussion

This cross-sectional study aimed to investigate the characteristics of osteoporosis and fracture risks in northwest China by assessing the prevalence of osteoporosis using QUS and calculated their fracture risks using the FRAX tool. A total of 1429 participants (1295 women and 134 men) were included, and the effects of age, sex, and anthropometric measurements on BMD and fracture risks were examined to provide a

general description of osteoporosis in the population of northwest China. Our study revealed an overall prevalence of osteoporosis of 42.34%, with a higher prevalence among females (44.56%) compared to males (20.90%). In terms of BMD, sex, age, and height were significant predictors of T score, with age negatively predicting T scores in females and height positively predicting T scores in both sexes. In terms of fracture risks, age and height were positive predictors of MO, while weight was a negative predictor. The results regarding HP were consistent with those for MO, except for the T score, which was a positive predictor of HP.

The prevalence of osteoporosis and related fracture risks pose a significant public health concern, albeit with considerable variability noted across different investigations. The distribution of BMD and osteoporosis populations in the northwest region has not been systematically studied. In China, Zhang et al compiled a reference BMD database in 2014 by pooling data from 139 912 Chinese adults, revealing that the age-standardized prevalence of osteoporosis was 23.9% and 12.5% in women and 3.2% and 5.3% in men aged >50 years at the lumbar spine and femoral neck, respectively [17]. A recent comprehensive cross-sectional study on the prevalence of osteoporosis among 20 416 participants in mainland China, assessing clinical fracture and related factors, estimated that the prevalence of osteoporosis among those aged 40 years or older was 5.0% in men and 20.6% in women [18]. A study conducted in Jilin Province, Northern China, examining the prevalence of osteoporosis defined by BMD at the distal forearm, reported a prevalence of 19.8% in men and 36.9% in women aged over age 50 years [19]. In our study, which utilized radial QUS to assess the prevalence of osteoporosis in northwest China, we found an overall prevalence of 42.34%, with higher prevalence among females (44.56%) than males (20.90%), consistent with the findings in Jilin Province. However, another study, defined by BMD at radius, conducted in Gansu, another province in northwest China, yielded a prevalence of 9.65% for postmenopausal women and 8.08% for men [20], which is much lower than in other reports. Differences in inclusion and exclusion criteria, population size, regions, genetic factors, and measurement methods and sites all can affect the distribution of BMD and osteoporosis in a population, making the production of representative studies one of the current challenges. The present study supplements the literature on the characteristics of osteoporosis in northwest China.

Our study suggests that demographic factors, such as sex, age, height, and weight, play a role in determining BMD and the development of osteoporotic fractures, and this relationship may vary by sex. In terms of BMD, sex, age, and height were significant predictors of T score, with age negatively predicting T score in females, similar to previous findings, and height positively predicting T score in both sexes. The predictive value

of height for BMD is controversial. In a 15-year follow-up including 1421 postmenopausal women, Forsmo et al found that shorter height was accompanied by a lower forearm BMD, and height was somewhat predictive of BMD [21], and this was similar to our findings. However, some studies found that height does not correlate with BMD [22]. Nicholson et al found no association between shorter height and lower BMD in a cross-sectional study of 222 individuals [23]. The relationship between height and BMD may need to be assessed by studies with larger sample sizes.

In addition, we included the fracture risk score to complement the description of the study population, and found the 10-year risk of major osteoporotic fracture was $(3.57 \pm 1.21)\%$ for the total population and $(1.02 \pm 0.79)\%$ for hip fracture. We found that the risk of fracture was higher in women than in men, which is similar to previous findings [24,25]. However, the prevention and treatment of osteoporotic fracture in men should not be neglected because they tend to have worse outcomes and poorer treatment rates. In addition, we believe the FRAX model may underestimate the actual fracture probability in China [26,27]. Our study found that multiple demographic and clinical factors play important roles in the development of osteoporotic fractures, and that these relationships may vary by sex. In particular, our results highlight the importance of age, height, weight, and T score as key predictors of fracture risk, and suggest that heavier weight may have a protective effect against fractures in females. Our findings are consistent with previous research [28,29].

In addition to the factors we focused on, other confounding factors, including dietary patterns, lifestyle choices, medication usage, and stress levels, may contribute to the difference in prevalence of risk factors between our study and other studies in China. The role of diet is particularly significant in relation to osteoporosis, as it is one of the few modifiable risk factors. The Mediterranean diet has proven to be beneficial to BMD [30], and Dietary Approaches to Stop Hypertension may improve lumbar spine BMD [31]. The diet pattern is the high-carbohydrate diet that is common in northwest China. The types of foods consumed were generally lacking diversity and the main energy sources were rice and noodles. A cross-sectional study in northwest China found that a high-carbohydrate diet was associated with a higher risk of frailty and pre-frailty [32]. This may account for part of the vast regional difference. Maintaining a healthy lifestyle, characterized by physical activity and sun exposure, is also beneficial for the preservation and enhancement of bone density. Conversely, unhealthy lifestyle habits such as smoking and excessive alcohol consumption can decrease bone density. In terms of medication usage, calcium and vitamin D play a crucial role in osteoporosis prevention, and engaging in outdoor activities promotes exposure to sunlight, which aids vitamin D synthesis.

Low vitamin D status is prominent in mainland China, especially among adults [33]. A cross-sectional study including 11157 healthy participants found that vitamin D deficiency is highly prevalent in northwest China (82.5% in men and 81.1% in women), especially among young physically inactive and overweight women with limited sunlight exposure [34]. Notably, Follis et al discovered a potential correlation between heightened social stress and bone loss in a study involving 11 020 postmenopausal women [35]. However, the relationship between regional differences in these confounding factors and BMD requires larger epidemiological studies.

It is important to note some potential limitations of this study. First, an analysis of a northwestern Chinese population led us to our conclusion. Therefore, the results of the study should not be generalized to all regions of China. Second, the number of females and males in the study population failed to ensure quantitative consistency, so further studies with larger sample sizes are needed to investigate the prevalence of osteoporosis in the Chinese population and its associated factors.

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Conclusions

We found an overall prevalence of osteoporosis of 42.34%, with a higher prevalence among females (44.56%) compared to males (20.90%) in northwest China. In terms of BMD, sex, age and height were significant predictors of T score, with age negatively predicting T score in females and height positively predicting T score in both sexes. In terms of fracture risks, age and height were positive predictors of MO, while weight was a negative predictor. The conclusion for HP was consistent with that of MO, except for the T score, which was a positive predictor of HP.

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