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Association between Bone Mineral Density and Dietary Patterns in Elderly Women in Guangxi: A Cross-Sectional Study in China

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Abstract: *This study aimed to investigate the relationship between dietary patterns and bone mineral density (BMD) in elderly women, analyze potential risk factors and provide a reference for the prevention of osteoporosis (OP). The study was conducted from December 2018 to November 2019 in Gongcheng Yao Autonomous County, Guangxi, and a cross-sectional survey was conducted using the whole cluster random sampling method. In this study, older women ≥60 years old were selected for physical examination, baseline population survey and food frequency questionnaire (FFQ). Dietary patterns were analyzed using factor analysis, and the relationship between dietary patterns and the prevalence of OP was assessed using a binary logistic regression model. According to statistical analysis of data, a total of 666 elderly women were included in this study, and their prevalence of OP was 53.45%. The differences in ethnicity, education level, Body mass index (BMI), Age, Hipline (Hip), Waist circumference (WC), and High-density lipoprotein cholesterol (HDL-C) were statistically significant (P < 0.05) in the non-OP group compared with the OP group. The prevalence of OP was high among elderly women in a rural county in Guangxi, China. The analysis results show that a dietary pattern with relatively high intake of edible oil and salt may be a risk factor for developing OP. It is recommended that in daily life, elderly women should maintain a healthy weight, eat a balanced diet, and reduce the intake of oil and salt to promote bone health.*

Keywords: *Dietary Patterns; Bone Mineral Density; Osteoporosis; Women*

1. Introduction

Osteoporosis (OP) is a progressive disease characterized by low bone mineral density (BMD) and deterioration of bone microarchitecture, leading to decreased bone strength and fragility fractures[1]. OP can lead to brittle fractures of the spine, proximal femur, and distal radius, which seriously affect the quality of life of patients. So it has become an important public health problem. The loss of bone mineral content (BMC) in women occurs mainly after menopause, due to an imbalance between the bone resorption process (role of osteoclasts) and the bone formation process (role of osteoblasts). Epidemiological studies have shown that the incidence of fractures due to postmenopausal OP is higher than the incidence of heart disease, stroke or even breast cancer[2]. OP is more prevalent in elderly menopausal women and has a higher rate of ageing-related OP. The prevalence of OP in women worldwide was estimated to be 23.1% in a meta-analysis study by Salari et al[3]. Another meta-analysis found that the prevalence of OP was 34% in Iranian women over 60 years of age[4]. And the prevalence rate of OP was 61.17% among Chinese women over 80 years old[5]. The clinical OP in the elderly not only leads to an increased risk of local fracture, but also increases the incidence of secondary vascular and nerve damage, which increases the rates of disability and morbidity and mortality of the patients[6,7].

Genetics, lifestyle, nutrition, disease, drug use, and metabolism are considered to be the main factors contributing to OP. Among these, diet is the main intervenable influence known to affect bone health and may explain to some extent the differences in skeletal outcomes in different populations. For example, high consumption of soy and dairy products is important in the prevention of OP[2]. Given that nutritional intake and dietary habits affect bone health throughout the lifespan, both at peak bone mass and to maintain bone mass during adulthood. Therefore, dietary patterns are an integrated approach that can provide valuable options for measuring single nutrients or food intake and have been used to explore the relationship between diet and disease. In addition, the results of pattern analysis based on food groupings can be more directly translated into dietary guidelines for the general public[8].

The relationship between nutrition and osteoporosis has received increasing attention in recent years. For example, supplementation with protein, lipids, carbohydrates, calcium, phosphorus, magnesium, and nutrients such as vitamin D, vitamin C, and vitamin K can reduce the risk of developing osteoporosis[9]. Probiotics and prebiotics in milk and dairy products as well as plant-based beverages can regulate bone renewal[10]. Current research focuses more on the correlation between one or more foods or nutrients and osteoporosis, and single nutrient exposures may underestimate the synergistic or antagonistic effects between foods. In contrast to single foods or nutrients, dietary patterns can provide a comprehensive picture of dietary exposure in a population and serve as a comprehensive indicator of individual dietary nutrient intake to predict disease occurrence. Guangxi Gongcheng Yao Autonomous County has been recognized as the "Hometown of Longevity in China"[11] and the reasons for the longevity of local residents are closely related to the unique geomorphology of the region and the dietary habits of ethnic minorities. However, there is still little evidence to study the relationship between dietary patterns and osteoporosis in elderly women in this region. Therefore, it is essential to focus on the relationship between osteoporosis and dietary patterns in this region.

The aims of this study were to understand the prevalence of osteoporosis and its relationship with dietary patterns in this ethnic minority area, to assess the bone health of rural women over 60 years of age in a county in Guangxi, and to provide a theoretical basis for the prevention and control of osteoporosis in this area as well as reasonable dietary guidance.

2. Methods

2.1. Study design and participants

This study was conducted in Guangxi Gongcheng Yao Autonomous County from December 2018 to November 2019 using whole cluster random sampling method for cross-sectional survey. Study subjects were selected who met the following criteria: (1) Women aged ≥ 60 years, (2) have complete BMD test data, and (3) voluntarily enrolled in this study and signed an informed consent form. Exclusion criteria were as follows: (1) treatment with anti-OP drugs or application of drugs therapy affecting bone metabolism, (2) suffering from various acute and chronic diseases that affect bone metabolism (such as hyperthyroidism, rheumatoid arthritis, systemic lupus erythematosus, and Parkinson's disease), and (3) core influencing factors: missing data on age, sex, height and weight.

A total of 2742 participants filled out the complete food frequency questionnaire(FFQ), among which there were 1,404 older participants aged 60 and above, and 666 were finally included in the study according to the inclusion exclusion criteria. The study was approved by the Ethics Committee of Guilin Medical College (No.20180702-3). Written informed consent was obtained from all subjects.

2.2. Definition of OP

Participants measured BMD in the terminal third of the radius using ultrasound bone densitometry. According to the diagnostic criteria of the World Health Organization and the information provided by the manufacturer of the bone densitometer, the diagnostic criteria for OP was defined as $T \leq -2.5$ for OP[12].

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2.3. Covariates

Marital status was divided into two groups: married or cohabiting, and unmarried or divorced. Meanwhile, based on years of education, educational attainment was divided into three groups: elementary school and below, middle school, and high school and above. Subjects measured their weight with a calibrated electronic digital scale and height with a safe portable rapid measuring device. Waist circumference (WC) was measured at 1 cm above the navel with a soft ruler. Body mass index (BMI) was calculated by weight (kg)/height (m2). Participants were classified as underweight (BMI < 18.5 kg/m2), normal weight (BMI 18.5-23.9 kg/m2), overweight (BMI 24.0-27.9 kg/m2), and obese (BMI ≥ 28.0 kg/m2)[13].

The fasting venous blood of the examined person was collected by a nurse at the local township health physical examination center. Then, serum total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), fasting blood glucose (FPG), and glycosylated hemoglobin (HbA1C) were measured using an automated clinical chemistry analyzer (Hitachi 7600-020, Kyoto, Japan) in the laboratory of Gongcheng Yao Autonomous County People's Hospital.

2.4. Assessment of food intake

Diet was assessed using FFQ[14], which recorded the subjects' major food intake in the previous year, with food types including rice, noodles and corn, total vegetables, total fruits, legumes, beans and peas, nuts, bacon, and red meat, as well as offal, white meat, fish, seafood, aquatic products, eggs, milk, yogurt, alcohol, salt and cooking oil, for a total of 109 foods.

2.5. Quality control

The questionnaires were completed one-on-one between the surveyors and the respondents, and the surveyors received uniform professional training. During the survey, respondents were provided with baseline questionnaires and food frequency tables, carrying molds for measuring food and standard food charts. Professionals performed physical examination and all instruments were calibrated to standard before use. All data and information were double-entered and checked for consistency to ensure data accuracy.

2.6. Statistical analysis

We tested the normality of continuous variables by using the Kolmogorov-Smirnov test. All data for continuous variables that did not follow normality were expressed as median and IQR, and count data were expressed as percentages. The chi-square test was used to assess differences in categorical variables of the baseline data, meanwhile, the Mann-Whitney U test was used to describe differences in continuous variables in participants' clinical characteristics. Dietary patterns were analyzed by factor analysis and maximum orthogonal rotation methods, and we further explored the relationship between dietary patterns and the prevalence of OP performing the binary logistic regression analysis. Furthermore, data sets were created using EpiData 3.1 with parallel double input. All statistical analyses were performed using SPSS 28.0, and a P value < 0.05 was considered statistically significant.

3. Results

3.1. Characteristics of 666 study participants

A total of 666 elderly women were included in this study and the prevalence of OP in this population was 53.45%. Among them, 415 (62.31%) belonged to the Yao ethnic group, 223 (33.48%) were Han, and only 4.21% were of other ethnic groups. Marital status was unmarried or divorced with 210 (31.53%) people, and married or cohabiting with 456 (68.47%) people. The education level was 594 (89.19%) for elementary school and below, 48 (7.21%) for junior high school, and 24 (3.60%) for high school and above. There were only 4 (0.6%) smokers, 161 (24.17%) alcohol drinkers. BMI was low weight with 94 (14.11%) people, normal weight was 420 (63.06%) people, overweight was 127 (19.07%) people, and obese was 25 (3.75%) people. Insomnia had 335 (50.3%) people. The differences in ethnicity, education level, and BMI were statistically significant in the non-OP group compared with the OP group (P<0.05) (Table 1).

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Table 1: Characteristics of 666 study participants.

Characteristics	Non-OP(n=310)	OP(n=356)	*P*-value
Ethnicity,n (%)			0.007
Han	86(27.7)	137(38.5)	
Yao	207(66.8)	208(58.4)	
Others	17(5.5)	11(3.1)	
Marital status,n (%)			0.531
Unmarried or divorced	94(30.3)	116(32.6)	
married or cohabiting	216 (69.7)	240(67.4)	
Education,n (%)			0.034
Primary school and below	268(86.5)	326(91.5)	
Junior high school	25(8.1)	23(6.5)	
Senior high school and above	17(5.4)	7(2.0)	
Smoking,n (%)			0.627
No	309(99.7)	353(99.2)	
Yes	1(0.3)	3(0.8)	
Drinking,n (%)			0.359
No	230(74.2)	275(77.2)	
Yes	80(25.8)	81(22.8)	
BMI(kg/m2),n (%)			0.002
Underweight	33(10.6)	61(17.1)	
Normal weight	189(61.0)	231(64.9)	
Overweight	71(22.9)	56(15.7)	
Obese	17(5.5)	8(2.3)	
sleeplessness,n (%)			0.868
No	153(49.4)	178(50.0)	
Yes	157(50.6)	178(50.0)	

BMI: body mass index.

3.2. The clinical characteristics of the study participants

The differences in Age, Hip, WC, and HDL-C were statistically significant in the non-OP group compared with the OP group (P<0.05). (Table 2).

Table 2: The clinical characteristics of the study participants, (M (P25,P75))

Characteristics	Non-OP (n=310)	OP (n=356)	*P*-value
Age, y	65(62, 68)	67.5(64,72)	0.000
Hip, cm	88(83,91.63)	86(82,90)	0.000
WC, cm	78(72,86)	74.5(68,82)	0.000
Grip,kg	17.7(14.4,21.03)	17.3(13.3,20.2)	0.157
LDL-C, mmol/L	3.62(3.07,4.23)	3.69(2.95,4.34)	0.766
HDL-C, mmol/L	1.75(1.55,2.04)	1.89(1.62,2.18)	0.001
TG, mmol/L	1.14(0.78,1.76)	1.06(0.8,1.56)	0.182
TC, mmol/L	5.75(5.14,6.41)	5.79(5.20,6.54)	0.462
CREA, mmol / L	60(54,69)	60(52.25,69)	0.427
UA, mmol/L	269(228,319.25)	262(222,307)	0.185
HbA1C (%)	5.8(5.5,6.2)	5.9(5.6,6.1)	0.646
GLU, mmol/L	4.87(4.59,5.29)	4.99(4.57,5.49)	0.068

Hip: hipline; WC: waist circumference; LDL-C: low-density lipoprotein cholesterol; HDL-C: high-density lipoprotein cholesterol; TG: triglycerides; TC: serum total cholesterol; CREA: creatinine; UA: uric acid; HbA1C: glycosylated haemoglobin; GLU: glucose.

3.3. Meal pattern analysis

The factor loading matrix of these dietary patterns was shown in Table 3. The dietary pattern of this population was established by factor analysis, and the KMO test statistic was 0.868, Bartlett's spherical

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test $\chi2$ = 2467.051, P<0.001, indicating that the dietary data of the population surveyed in this area were suitable for factor analysis. The principal component analysis in factor analysis was used to extract the common factors, and the results showed that the four dietary patterns were more meaningful, and the characteristic roots of the four factors were greater than 1, 3.547, 2.065, 1.510, and 1.097, respectively. The cumulative variance contribution of the four factors was 51.362%, 22.167%, 12.904%, 9.436%, and 6.855%, respectively. The dietary patterns were analyzed by factor analysis and maximum variance orthogonal rotation methods, and the initial factor loadings were rotated by maximum variance orthogonal rotation to obtain the rotated factor loading matrix, and the dietary patterns were named by the food groups with larger loading coefficients. In this population, four dietary patterns were analyzed. The first, plant-based dietary pattern, mainly included coarse grains, vegetables, fruits, beans and soy products, mushrooms, nuts, eggs and dairy. The second was animal-based dietary pattern, with the characteristic of high intakes of red meat, white meat, offal, and aquatic products. Third, the oil and salt pattern was characterized by a relatively high intake of edible oils and salt. The last one, the grain-alcohol pattern, which was based on cereals and alcohol.

Table 3: Factor load of dietary pattern.

Type of Food	plant-based dietary pattern	animal-based dietary pattern	the oil and salt pattern	grain-alcohol pattern
Grain	0.097	0.173	-0.016	**0.629**
Whole grains	**0.440**	0.047	0.351	0.251
Fresh vegetables	**0.649**	0.173	0.007	0.248
Total fruits	**0.725**	0.256	0.129	0.152
Bean products	**0.674**	0.380	0.037	0.004
Nuts	**0.640**	-0.152	0.235	-0.125
Red meat	0.097	**0.760**	0.206	-0.045
White meat	0.533	**0.415**	-0.016	-0.190
Visceral	0.179	**0.748**	0.042	0.120
Pickled foods	0.580	**0.257**	0.076	0.149
aquatic products	0.328	**0.547**	-0.054	0.012
Egg and milk	**0.426**	0.054	0.046	-0.036
Mushrooms	**0.730**	0.213	-0.018	-0.051
Alcoholic drinks	0.036	0.137	0.025	**-0.660**
Oil	0.214	-0.010	**0.765**	-0.140
salt	-0.028	0.164	**0.819**	0.054

3.4. Binary logistic regression analysis of dietary patterns and OP

Table 4: Binary logistic regression analysis of dietary patterns and OP

Variables	Model 1		Model 2	
	β	OR 95%CI	β	OR 95%CI
plant-based dietary pattern				
Q1		1		1
Q2	0.326	1.385(0.861,2.230)	0.100	1.094(0.655,1.829)
Q3	0.098	1.103(0.691,1.761)	-0.063	0.948(0.573,1.571)
Q4	-0.151	0.860(0.549,1.347)	-0.181	0.830(0.514,1.340)
animal-based dietary pattern				
Q1		1		1
Q2	0.075	1.077(0.686,1.691)	0.149	1.165(0.719,1.889)
Q3	-0.001	0.999(0.638,1.567)	-0.026	0.963(0.599,1.549)
Q4	0.110	1.116(0.716,1.740)	0.111	1.111(0.696,1.774)
the oil and salt pattern				
Q1		1		1
Q2	0.300	1.350(0.866,2.106)	0.071	1.052(0.651,1.700)
Q3	0.716	2.047(1.306,3.207)*	0.609	1.841(1.144,2.962)*
Q4	0.273	1.315(0.849,2.035)	0.257	1.280(0.803,2.040)
grain-alcohol pattern				
Q1		1		1
Q2	-0.128	0.880(0.561,1.379)	-0.122	0.875(0.554,1.409)
Q3	-0.061	0.940(0.597,1.482)	-0.083	0.933(0.575,1.511)
Q4	0.209	1.232(0.790,1.921)	0.190	1.213(0.758,1.939)

*Compared with Q1, P<0.05.
Model 1: without further adjustment.
Model 2: covariates adjusted for Ethnicity, Education, BMI, Age, WC, Hip, HDL-C.

The factor scores of each dietary pattern were divided into quartiles from lowest to highest, and named as Q1, Q2, Q3 and Q4 groups respectively. Whether or not they had OP was used as the dependent variable, and the groupings of the four dietary patterns were included in the equation for multi-factor logistic regression analysis. The results showed that in model 1, moderately high intake level (Q3) of oil and salt dietary pattern (OR=2.047, 95% CI=1.306 to 3.207) was a risk factor for developing OP. In model 2, after correcting for ethnicity, education, BMI, age, WC, hip, and HDL-c, the moderately high intake level (Q3) of the oil and salt dietary pattern (OR=1.841, 95% CI=1.144-2.962) remained an independent risk factor for OP, and there were found no statistically significant differences between the other dietary patterns and the prevalence of OP (P>0.05). (Table 4).

4. Discussion

In the present study, the prevalence of OP in the rural elderly female population was 53.45%. A cross-sectional study conducted in rural Henan province that included 8475 participants[15] showed that approximately 50% of participants in the general population in rural China had osteopenia and 16.24% had OP. Rashed[16] et al showed in a study of 1079 Jordanian postmenopausal women aged 45-84 years that OP and bone reduction had a higher prevalence of 37.5% and 44.6%, respectively. Both of which differed from the prevalence of OP in our study population, which may be partly due to the predominance of the Yao ethnic group (62.31%) in the population we investigated, and the differences in these results may be related to the ethnicity, age structure, local geography, socioeconomic level, lifestyle, and different dietary habits in ethnic minority areas.

In this study, we clarified the relationship between dietary patterns and OP in elderly women aged 60 years and older in a rural Chinese population. Logistic regression analysis showed that dietary patterns with relatively high intake of edible oil and salt at moderately high intake levels compared with low intake levels demonstrated that they could increase the risk of developing OP. The trend remained after adjusting for ethnicity, literacy, BMI, age, WC, hip, and HDL-C. An analysis by Kim[17] et al of 3,635 postmenopausal women also suggested that excessive daily sodium intake was associated with a higher prevalence of OP. However, in a retrospective study[18], high salt intake significantly increased the secretion of the bone turnover marker CTX-I in Korean postmenopausal women, thus suggesting that excessive sodium intake may accelerate bone turnover and increase the risk of OP. Hamid[19] found that a high salt diet could impair bone health by enhancing osteoclast Th17 cells and suppressing antiosteoclast Treg cells.These were similar to the results of the present study. And too much fat intake could also have an impact on bone density. The ketogenic diet (KD)[20] is a high-fat, moderate protein, and low-carbohydrate diet, KD can lead to OP and reduced bone mass in experimental mice. Meanwhile, Shu et al[21] used a high-fat diet (HFD), a type of ketogenic diet, to feed C57BL/6J mice for 12 weeks and found that it caused significant, systemic bone loss and concurrent stimulation of osteoclast formation. In population-based epidemiology[22], a higher incidence of OP and fractures were found in people with a regular high-fat diet in their daily lives. The results of the present study were also identical to those of previous scholars. Meanwhile, numerous studies had shown[23,24] that high intake of oil and salt is inextricably linked to the occurrence of many chronic diseases such as hypertension and chronic kidney disease. It was recommended that this population should reduce the intake of oil and salt and maintained a diet with less oil and salt, so as to prevent the occurrence of chronic diseases.

In this study population, dietary patterns were not associated with OP, except for the oil and salt dietary pattern. Vegetarian diets with a high intake of fruits and vegetables, etc., usually contained more bone-protective nutrients such as magnesium, potassium, vitamin K, and antioxidant and anti-inflammatory phytonutrients[25]. However, available evidence suggested that vegetarian diets, especially vegan diets, were associated with lower BMD[26]. And more foreign scholars[27] confirmed that dietary patterns rich in vegetables and fruits prevent OP. Flavonoids in soy, especially isoflavones, mimic estrogenic activity, and high intake of beans and soy products, milk and dairy products reduced the risk of OP[28,29]. Nuts and kernels were rich in calcium and potassium, which helped to reduce the loss of calcium in the urine. Meanwhile, milk and nuts were also rich in protein, and protein increased calcium absorption and storage, which was beneficial for preventing and delaying the occurrence of OP[30]. However, in this study, the plant-based dietary pattern didn't show a protective effect on OP, which may be related to the different intakes and types of plant-based foods in different populations. A systematic review of dietary patterns with high intake of fish and meat (or their derivatives)[25] showed that protein intake from fish or meat was not harmful to bone, similar to the results of the present study. However, while meat diets negatively affected bone metabolism in Western diets, these effects could not be demonstrated in Mediterranean or Asian diets. In Asian populations, in contrast, fish diets could increase BMD and reduced fracture risk[31]. In animal-based dietary patterns, it was possible that foods with OP-lowering or OP-elevating properties were present at the same time and that the food effects interacted to cancel out resulting in no correlation with OP prevalence. A cross-sectional study conducted in the U.S. middle-aged and elderly population found that[32] whole grains were associated with a lower incidence of OP. Because whole grains were rich in dietary fiber, calcium, iron, vitamin B complexes, vitamin E and phytochemicals, they were beneficial for bone health. It had been demonstrated that alcohol was negatively associated with bone health mainly by interfering with calcium homeostasis and that chronic excessive alcohol consumption could not only trigger alcohol-induced osteoporosis (AOP)[33], but heavy drinkers could increase the risk of any fracture, including hip and vertebral fractures. Interestingly, in another cross-sectional study, light drinkers (1-9 g/d for women) in menopausal women had significantly higher whole-body, lumbar and femoral BMD than non-drinkers[34]. In this study, the grain-alcohol dietary pattern was too homogeneous in terms of food groups to be suitable for replication, but suggests that light alcohol consumption may be beneficial for bone health in elderly women.

This study had several strengths and limitations. First, as far as we know, this was the first study to investigate the relationship between different dietary patterns and the risk of osteoporosis in Guangxi Gongcheng Yao Autonomous County, thus complementing the data on osteoporosis status and dietary habits among older women in Guangxi. Second, we used a validated semi-quantitative FFQ and ensured that the data collected were accurate by means of face-to-face interviews. In addition, adjustments for potential known confounders increased the reliability of the analysis. However there were some limitations, firstly, this was a cross-sectional study and it was not possible to determine a causal relationship between dietary patterns and the onset of osteoporosis. Second, this study was conducted only in Guangxi Gongcheng Yao Autonomous County, a region where most of the residents are from ethnic minorities and which has been recognized as the "Hometown of Longevity in China" because of its unique landscape and dietary habits. Therefore, the generalizability of our results to other populations was limited.

5. Conclusions

The high prevalence of OP among elderly women in rural areas of a county in Guangxi is demonstrated by a diet pattern with relatively high intake of edible oil and salt that can increase the risk of developing OP. It is recommended that in daily life, elderly women should maintain a healthy weight, eat a balanced diet, and reduce the intake of oil and salt to promote bone health.

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Availability of data and materials

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

Ethics approval and consent to participate

Our research protocol was approved by the Ethics Committee of Guilin Medical University (No.20180702-3). All participants or a next of kin of the participants were provided written informed consent before data collection. The present study was performed in accordance with the Declaration of Helsinki.

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