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Original article

Clinical study on the influence of tea drinking habits on bone mineral density and osteoporosis in postmenopausal women in Fuzhou city, China

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Summary. *Background and aims:* Recently, considerable attention has been given to tea intake as a source of plant polyphenols which may be preventive for osteoporosis (OP), but the previous reports of that were inconsistent. Therefore. the study sought to analyze the influence of tea drinking habits on bone health in Chinese postmenopausal women in Fuzhou city after adjusting for the influence of confounding factors. *Methods:* A total of 1134 cases of postmenopausal women living in Fuzhou city were enrolled and 947 cases met the requirements. There were 502 cases in the non-tea-drinking group, 326 cases in the occasional-tea-drinking group, and 119 cases in the daily-tea-drinking group. Researchers surveyed Body mass index (BMI) was calculated based on height and weight. Bone mineral density (BMD) was measured by dual-energy X-ray (DXA) absorptiometry and a health examination survey was conducted, including the demographics, reproductive and menstrual history, lifestyle and history of diseases. *Results:* Among the 947 postmenopausal women, 53.1% were non-tea-drinkers, 34.42% were occasional tea-drinkers, and 12.57% were daily-tea drinkers. The BMD of lumbar spine of the daily-tea-drinking group was (0.788±0.115) g/cm2, which was significantly higher than that of the non-tea-drinking group's (0.737±0.106) g/cm2 ($p< 0.001$). The BMD of total femur of the daily tea-drinking was (0.754±0.105) g/cm2, which was significantly higher than that of the non-tea-drinking group's (0.737±0.106) g/cm2($p< 0.001$). The results of multiple linear regression analysis demonstrated that daily tea-drinking was positively correlated with the BMD of the lumbar spine and total femur. The results of multiple logistic regression analysis demonstrated that drinking tea daily was an independent protective factor for osteoporosis. *Conclusion:* Drinking tea daily helps Chinese postmenopausal women maintain BMD of the lumbar spine and the total femur, and it could be an independent protective factor for osteoporosis.

Keywords: Tea drinking habits, Postmenopausal women, Bone mineral density, Osteoporosis

Introduction

Osteoporosis (OP) is a skeletal metabolic disease characterized by increased bone reabsorption and decreased bone formation, which results in declined bone mineral density (BMD), degraded bone microstructure, and increased risk of fracture (1). China's population is rapidly aging (2), and the latest data indicate that 15% (20243 million) of China's population was over 60 years old in 2013 (3),and it is expected that this population will increase to 31.2% by 2050 (4); Since age is one of the significant risk factors for OP (5-10), the number of OP patients in China will increase to more than 120 million by then (5), which will become a considerable threat to public health (11).

Tea is one of the most popular beverages in the world (12) and an essential source of plant polyphenols in the diet (13). In Fuzhou city, China, the habit

of drinking tea (mainly oolong tea) prevails. Studies have confirmed that tea has excellent antioxidant and health effects (14), which can reduce not only the mortality of respiratory and cardiovascular diseases, but also reduce the risk of cancer and mental illness (15-23). However, the previous reports were inconsistent with the effect of tea drinking habits on BMD. Some previous studies showed that tea drinking had a positive correlation with BMD (24-28), and oolong tea had a higher positive correlation (29), while others showed that no correlation was found (30-32).This study, which was conducted in Fuzhou City, Fujian Province, China, not only compared the demographics among non-tea-drinking group, occasional-tea-drinking group, and daily-tea-drinking group but also included factors such as reproductive and menstrual history, lifestyle and medical history so that we can do further analysis of the influence of tea drinking habits on Chinese postmenopausal women with BMD and OP.

Materials and Methods

Participants

The study was an analytical cross-sectional study conducted from October 2013 to October 2019. A total of 1134 cases of postmenopausal women who visited the OP specialist clinic of Fujian Academy of Chinese Medical Sciences were enrolled into this study.

The inclusion criteria were:

1) Patients who have been menopause for more than two years;
2) Patients who have lived in Fuzhou city for more than ten years;
3) Patients who have signed informed consent.

The exclusion criteria were:

1) patients with secondary OP or diseases affecting bone metabolism;
2) patients taking drugs that affect bone metabolism for an extended period;
3) patients receiving hormone replacement therapy;
4) patients who did not complete the entire study.

Eligible 947 participants were divided into three groups: 502 of them were in the non-tea-drinking group, 326 of them were in the occasional-tea-drinking group, and 119 of them were in the daily-tea-drinking group (more than 1 cup of tea per day). Each one of the eligible participants took the health examination survey and had BMD measurement.

Health Examination Survey

A questionnaire was designed to collect some data including age, age at menarche, age at menopause, milk-drinking habits (never, occasional/daily), sunlight exposure time (<1h, ≥1h), sports time (<1h, ≥1h), frequency of pregnancy, number of children breastfed, gastrointestinal diseases (no, yes), hypertension (HTN) (no, yes), coronary artery disease (CAD) (no, yes), awareness of OP (no, yes), calcium supplementation (no, yes), and body mass index (BMI) was calculated from measured height and weight. All participants were asked to complete the paper-based questionnaires during face-to-face interviews by the researchers.

Data collection

After the questionnaire survey was collected, the data were recorded by researchers according to the double-blind entry rules and then checked by a second independent person. Questionnaires with more than 5% missing data were excluded and then 947 participants were eligible.

BMD Measurement

The BMD measurement was carried out using the model Discovery W dual-energy X-ray bone densitometer (coefficient of variation 1.0 CV%, accuracy 0.25%) of Hologic Corporation, USA. BMD of orthotopic lumbar vertebra (L2~4) and left hip was detected. Bone health was determined using T-score criteria from the World Health Organization; T-score lower than -2.5 SD is defined as osteoporosis (33).

Ethics statement

Written informed consent was obtained from each participating individual.

Statistical Analysis

Continuous variables were first tested for normality with the Shapiro-Wilk test; The continuous variables that follow the normal distribution are expressed as mean± standard deviation (SD) and analyzed via the One-way ANOVA test followed by the Bonferroni post hoc tests for pairwise comparisons if there were statistical differences among the groups. The continuous variables that do not follow the normal distribution are expressed as median (Interquartile Range, IQR) and analyzed via the Kruskal-Wallis H test followed by the LSD post-hoc tests for pairwise comparisons if there were statistical differences among the groups. Categorical variables are expressed in frequencies (percentage) and analyzed via the Chi-square test. Binary univariate logistics regression (Enter method) was performed to determine the relationship among tea drinking habits, associated factors and OP. And variables with significant differences in the univariable analyses were incorporated into multiple logistic regression analysis (Forward-LR method). Multiple linear regression analysis was performed to determine the influence of tea drinking habits on BMD. The continuous variables were used Stepwise method, and the categorical variables were transformed to dummy variables and then used Enter method. Statistical analysis was performed using SPSS 22.0 (IBM Corp, Armonk, NY, USA). All statistical tests were 2-sided, and a P-value significance threshold of 0.05 was set.

Results

Characteristic of the participants

A total of 947 participants were included in this study. Among them, there were 502 (53.01%) in the non-tea-drinking group, 326 (34.42%) in the occasional-tea-drinking group, and 119 (12.57%) in the daily-tea-drinking group. The characteristics of the group, as shown in Table 1, the age at menarche and age at menopause of the occasional-tea-drinking group were significantly higher than those of the non-tea-drinking group (p<0.05, p<0.001, respectively), the BMD of lumbar spine and the total femur of the occasional-tea-drinking group and the daily-tea-drinking group were higher than those of the non-tea-drinking group (p <0.001).

Comparison of associated factors for OP of the participants

The Chi-square test was performed on the associated factors of the three groups. As shown in Table 2, there were significant differences in the distribution of tea-drinking habits ($\chi2$= 5.590, p= 0.018), frequency of pregnancy ($\chi2$= 4.569, p= 0.033), gastrointestinal diseases ($\chi2$= 4.569,p= 0.033), calcium supplementation ($\chi2$= 4.339, p= 0.036), awareness of OP ($\chi2$ = 6.690, p= 0.010), and number of children breastfed ($\chi2$ = 8.511, p= 0.004).

Correlations between associated factors and BMD of the participants

Multiple linear regression analysis was performed to determine the relationship between tea drinking habits and BMD after adjusting for the influence of confounding factors. The BMD of each part was set as the dependent variable, and the relevant factors were set as independent variables for analysis. The continuous variables were used Stepwise method, and the categorical variables were transformed to dummy variables and then used Enter method. As shown in Table 3, daily tea drinking had a positive correlation with the BMD of the lumbar spine and the total femur (p< 0.001, p< 0.01, respectively).

Association between associated factors and OP of the participants

Binary logistic regression was performed to determine the influence of daily tea drinking habits on

OP. Firstly, univariate logistic regression analysis was performed with OP as the dependent variable and associated factors as the independent variables (enter method). As shown in Table 4, age (OR= 1.064,95% CI: 1.042-1.085, p< 0.001), BMI (OR= 1.057,95% CI: 1.012-1.103, p= 0.013), age at menarche (OR= 1.088, 95% CI: 1.02-1.161, p= 0.011), age at menopause (OR= 0.948,95% CI: 0.913-0.983, p= 0.004), daily-tea-drinking (OR= 0.595,95% CI: 0.346-0.811, p= 0.003), frequency of pregnancy (OR= 1.117,95% CI: 1.015-1.23, p= 0.024), and number of children breastfed (OR= 1.312,95% CI: 1.126-1.528, p< 0.001) were independent influencing factors for OP. Secondly, multiple logistic regression analysis was performed with the above factors incorporated (stepwise method). The result shows that age (OR= 1.066,95% CI: 1.044-1.088, p< 0.001), BMI (OR= 1.006, 95% CI: 1.019-1.114, p= 0.005), menopausal age (OR= 0.941,95% CI: 0.906-0.978, p= 0.002), and daily-tea-drinking (OR= 0.575,95% CI: 0.371-0.890, p= 0.013) were independent influencing factors for OP. Among them, daily tea-drinking and menopause age were independent protective factors for OP, while BMI and age were independent risk factors.

Discussion

Tea is the second most popular beverage in the world. Over the past decade, tea consumption has increased by 10% and continues to grow (34). About 78% of global tea production is black tea, which is usually consumed in Western countries; 20% of it is green tea, which is usually consumed in Asian countries; the remaining 2% is oolong tea, which is mainly produced in Southern China (35) and pervasive among the participants in our research. Oolong tea is a typical semi-fermented traditional tea in China, which is very popular because of its unique flavor and taste (36). It is formed by enzymatic oxidation of green tea through semi-fermentation to form theaflavin and thearubin (37-38). Nevertheless, the fermentation process did not significantly change the activity of scavenging free radicals, and the theaflavin

Table 1. Baseline characteristics of the participants [a]

Variables	Non-tea-drinking group	Occasional-tea-drinking group	Daily-tea-drinking group
Number (n)	502	326	119
Age (year)	62(59,67)	61.5(57,66)	61(57,66)
BMI (kg/m^2)	23.175(21.473,25.323)	23.530(21.638,25.540)	22.890(20.810,25.150)
Age at menarche (year)	15(14,17)	**15(14,17)** [b]	15(14,16)
Age at menopause (year)	50(48,52)	**50(49,53)** [c]	50(48,53)
Lumbar spine BMD (g/cm^2)	0.737±0.106	**0.763±0.122**[c]	**0.788±0.115**[c]
Femoral neck BMD (g/cm^2)	0.670(0.589,0.750)	0.676(0.598,0.760)	0.684(0.625,0.764)
Greater trochanter BMD(g/cm^2)	0.595(0.538,0.677)	0.610(0.542,0.690)	**0.628(0.570,0.695)** [b]
Ward's triangle BMD(g/cm^2)	0.530(0.442,0.677)	0.536(0.455,0.643)	0.557(0.467,0.663)
Total femur BMD(g/cm^2)	0.737±0.106	**0.730±0.104**[c]	**0.754±0.105**[c]

[a] Values are presented as mean± SD or median (IQR). BMI = body mass index; BMD = bone mineral density. [b] p <0.05 compared with the non-tea-drinking group. [c] p <0.001 compared with the non-tea-drinking group.

Table 2. Results of comparison of the factors associated with OP[a]

Variables	**Non-tea-drinking group**	**Occasional-tea -drinking group**	**Daily-tea -drinking group**	χ^2	*P*
Milk-drinking habits					
Never	125(61.6)	49(24.1)	29(14.3)	2.459	0.117
Occasional/Daily	377(50.7)	277(37.2)	90(12.1)		
Calcium supplementation					
No	308(56.2)	176(32.1)	64(11.7)	4.399	**0.036**[b]
yes	194(48.6)	150(37.6)	55(13.8)		
Sun exposure time					
<1h	332(52.7)	220(34.9)	78(12.4)	0.006	0.938
≥1h	170(53.6)	106(33.4)	52(12.9)		
Sports time					
<1h	250(55.7)	149(33.2)	50(11.1)	2.913	0.088
≥1h	252(50.6)	177(35.5)	69(13.9)		
Frequency of pregnancy					
0	4(57.1)	1(14.3)	2(28.6)		
1	91(47.4)	73(38.0)	28(14.6)		
2	132(49.4)	105(39.3)	30(11.2)	5.590	**0.018**[b]
3	142(54.0)	85(32.3)	36(13.7)		
4	85(62.5)	40(29.4)	11(8.1)		
≥5	48(58.5)	22(26.8)	12(14.6)		
Number of children breastfed					
0	10(62.5)	4(25.0)	2(12.5)		
1	299(48.8)	236(38.5)	78(12.7)		
2	112(56.0)	64(32.0)	24(12.0)	8.511	**0.004**[c]
3	54(65.1)	17(20.5)	12(14.5)		
≥4	27(77.1)	5(14.3)	3(8.6)		
Gastrointestinal diseases					
No	239(51.0)	199(34.6)	83(14.4)	4.569	**0.033**[b]
Yes	209(56.2)	127(34.1)	36(9.7)		

HTN					
No	360(53.7)	231(34.5)	79(11.8)	1.042	0.307
Yes	142(51.3)	95(34.3)	40(14.4)		
CAD					
No	452(52.1)	305(35.2)	110(12.7)	2.071	0.150
Yes	50(62.5)	21(26.3)	9(11.3)		
Awareness of OP					
No	348(56.7)	193(31.4)	73(11.9)	6.690	**0.010**[b]
Yes	154(46.2)	133(39.9)	46(13.8)		

[a] Values are presented as n (%). HTN = hypertension; CAD = coronary artery disease. [b] *p< 0.05.* [c] *p< 0.01.*

has the same strong antioxidant properties as green tea (39).

The main component of tea is tea polyphenols, which prevent OP in three ways: First, tea polyphenols are abundant in epigallocatechin gallate (EGCG) (40-42) which can enhance the alkaline phosphatase activity of osteoblast-like cells (including Saos-2 cells and MC3T3-E1 cells) at the level of protein and gene expression, thereby increasing bone mineralization (43). Secondly, tea polyphenols can significantly promote osteoblast survival and reduce osteoblast apoptosis (44), thereby enhancing cell proliferation and differentiation and delaying BMD reduction (40, 45). Third, tea polyphenols can improve the metabolic state (46) and increase the level of circulating vitamin D in the body (47-48). Although tea contains caffeine, it can not only reduce osteoblast viability (49-51) but also accelerate the excretion of calcium (52). However, since tea polyphenols account for 25% to 35% of dry tea weight and caffeine only accounts for 2% to 4% of dry tea weight, the benefits of drinking tea may be higher than the disadvantages. This study demonstrated that daily-tea-drinking was positively correlated with the BMD of lumbar spine and total femur after adjusting for the influence of confounding factors; Daily-tea-drinking was an independent protective factor of OP. The results of this study suggest that daily-tea-drinking habits may help maintain high BMD and prevent OP in postmenopausal women.

The purpose of this study was to analyze the influence of tea drinking habits on BMD and OP, providing evidence for developing tea drinking habits in daily life to prevent OP. Compared with previous reports (30, 53-56), there are several advantages of our design. First, in this study we have been able to use data from a large population-based cohort of postmenopausal women. The total of 947 cases which met the requirements was sufficient to elucidate the influence of tea drinking habits. Second, the general characteristics of participants had certain geographical representation since all of the participants are local residents for Fuzhou city. Third, the results were more convincing, because we were able to determine the influence of tea drinking habits after adjusting for the influence of confounding factors by the comprehensive questionnaire. Nevertheless, one limitation of our study is that we were unable to detect the influence of tea types because of lack of information about this issue.

Conclusion

Our findings suggest that drinking tea daily may be beneficial to maintain the BMD of the lumbar spine and total femur in postmenopausal women in Fuzhou city, China, and could be an independent protective factor for OP. These findings add to the accumulating evidence of the relationship between tea-drinking habits and bone health, and are crucial to the primordial prevention of osteoporosis in daily life. Further studies are needed to determine the influence of different teas types on bone health.

Table 3. Results of multiple linear regression analysis of the factors associated with BMD

Variables	Lumbar spine		Femoral neck		Greater trochanter		Ward's triangle		Total femur	
	B	*p*	B	*p*	B	*p*	B	*p*	B	*p*
Constant	0.789	**<0.001**[c]	1.015	**<0.001**[c]	0.840	**<0.001**[c]	0.907	**<0.001**[c]	0.894	**<0.001**[c]
Age	-0.003	**<0.001**[c]	-0.006	**<0.001**[c]	-0.004	**<0.001**[c]	-0.008	**<0.001**[c]	-0.004	**<0.001**[c]
BMI	-0.003	**0.032**[a]	-		-		-		-	
Age at menarche	-		-		-		-0.003	0.053	-	
Age at menopause	0.003	**0.002**[b]	-		-		0.003	0.042	0.002	0.019
Tea drinking habits										
Non-tea-drinkers	Reference		Reference		Reference		Reference		Reference	
Occasional tea-drinkers	0.027	0.001	0.005	0.504	0.009	0.252	0.002	0.857	0.011	0.155
Daily-tea drinkers	0.057	**<0.001**[c]	0.013	0.261	0.022	0.056	0.010	0.483	0.029	**0.007**[b]
Milk-drinking habits										
Never	Reference		Reference		Reference		Reference		Reference	
Occasional/Daily	0.006	0.524	0.07	0.453	<0.001	0.997	0.017	0.132	-0.004	0.640
Calcium supplementation										
No	Reference		Reference		Reference		Reference		Reference	
Yes	-0.010	0.203	-0.001	0.863	0.001	0.899	<0.001	0.968	0.002	0.743
Sunlight exposure time										
<1h	Reference		Reference		Reference		Reference		Reference	
≥1h	-0.006	0.489	0.046	**<0.001**[c]	0.046	**<0.001**[c]	0.045	**<0.001**[c]	-0.003	0.667
Sports time										
<1h	Reference		Reference		Reference		Reference		Reference	
≥1h	0.003	0.684	-0.001	0.916	-0.008	0.324	-0.002	0.873	0.008	0.306
Frequency of pregnancy	-		-		-		-		-0.006	**0.026**[a]
Number of children breastfed	-		-		-		-		-	
Gastrointestinal diseases										
No	Reference		Reference		Reference		Reference		Reference	
Yes	0.010	0.165	-0.005	0.483	-0.009	0.233	-0.005	0.592	0.007	0.312
HTN										
No	Reference		Reference		Reference		Reference		Reference	
Yes	0.011	0.200	-0.014	0.107	0.004	0.677	-0.006	0.548	0.001	0.913
CAD										
No	Reference		Reference		Reference		Reference		Reference	
Yes	-0.013	0.331	0.032	0.022	0.030	**0.027**[a]	0.019	0.258	0.010	0.453
Awareness of OP										
No	Reference		Reference		Reference		Reference		Reference	
Yes	-0.003	0.713	-0.004	0.658	-0.013	0.093	-0.007	0.450	-0.002	0.819

ap< 0.05. bp< 0.01. cp< 0.001.

Table 4. Results of binary logistic regression analysis of the factors associated with OP

Variables	Univariable logistic regression			Multiple logistic regression		
	OR	**(95% CI)**	***p***	**OR**	**(95% CI)**	***p***
Age	1.064	(1.042,1.085)	**<0.001**[c]	1.066	(1.044,1.088)	**<0.001**[c]
BMI	1.057	(1.012,1.103)	**0.013**[a]	1.006	(1.019,1.114)	**0.005**[b]
Age at menarche	1.088	(1.02,1.161)	**0.011**[a]			
Age at menopause	0.948	(0.913,0.983)	**0.004**[b]	0.941	(0.906,0.978)	**0.002**[b]
Tea drinking habits			**0.010**[a]			**0.046**[a]
Occasional vs Never	0.798	(0.602,1.059)	0.118	0.897	(0.668,1.204)	0.469
Daily vs Never	0.529	(0.346,0.811)	**0.003**[b]	0.575	(0.371,0.890)	**0.013**[a]
Milk-drinking habits						
Occasional/Daily vs Never	1.046	(0.763,1.433)	0.780			
Calcium supplementation						
Yes vs No	1.292	(0.996,1.678)	0.054			
Sunlight exposure time						
≥1h vs <1h	1.002	(0.762,1.317)	0.988			
Sports time						
≥1h vs <1h	0.865	(0.668,1.12)	0.271			
Frequency of pregnancy	1.117	(1.015,1.23)	**0.024**[a]			
Number of children breastfed	1.312	(1.126,1.528)	**<0.001**[c]			
Gastrointestinal diseases						
Yes vs No	0.895	(0.687,1.166)	0.409			
HTN						
Yes vs No	1.110	(0.837,1.472)	0.470			
CAD						
Yes vs No	1.408	(0.89,2.228)	0.143			
Awareness of OP						
Yes vs No	1.216	(0.929,1.592)	0.154			

[a]*p< 0.05.* [b]*p< 0.01.* [c]*p< 0.001.*

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Conflicts of interest

Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

Abbreviations

OP = osteoporosis
BMD = bone mineral density
BMI = body mass index
DXA = dual-energy X-ray
BMI = body mass index
BMD = bone mineral density
HTN = hypertension
CAD = coronary artery disease.

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