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Caffeine intake and bone mineral density in postmenopausal women

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ABSTRACT

Aims: Osteoporosis is a metabolic bone disease characterized by low bone mass and deteriorated bone tissue. There is ongoing debate about the effect of caffeine intake on bone metabolism due to inconsistent study results. This study aimed to assess the association between caffeine intake and bone mineral density (BMD).

Methods: This single center cross-sectional study, prospectively enrolled postmenopausal women aged between 41 and 65 years who underwent bone mineral density measurement by dual-energy X-ray absorptiometry (DXA) at the lumbar spine and femoral neck. Caffeine intake was estimated using a food frequency questionnaire (FFQ) and a caffeine-specific FFQ. Patients consuming more than 260 mg/day caffeine were classified as high consumers.

Results: The study included 80 subjects (mean age: 57.1±5.6 years). Daily caffeine intake was 229.7±119.5 mg, and 36.3% (n=29) of the patients was classified as high consumers. The mean total T-score was -1.4±0.9 at the lumbar spine and -1.7±0.9 at femoral neck. High and low caffeine consumers had similar mean total T-score at the lumbar spine (-1.4±1.1 vs. -1.4±0.8, p=0.849). However, femoral neck mean T-score was significantly lower in high caffeine consumers (-2.0±0.9 vs. -1.5±0.7, p=0.033). The amount of daily caffeine intake showed a negative, moderate correlation with femoral neck T-score (r=-0.251, p=0.025).

Conclusions: The results of this study suggest that higher caffeine intake may be associated with lower T-scores on DXA of the femoral neck.

Introduction

Osteoporosis is a metabolic bone disease, characterized by low bone mass, deteriorated bone tissue and disrupted bone microarchitecture, which results in increased fracture risk and decreased quality of life. Osteoporosis is an important public health problem, associated with adverse health effects and economic burden. In parallel with the globally increasing aging population, osteoporosis is also increasing worldwide. Osteoporosis is diagnosed either through a history of a fragility fracture without a serious trauma or bone mineral density (BMD) measurement (1) by dual-energy X-ray absorptiometry (DXA).

The risk factors of osteoporosis can be classified as modifiable (low physical activity, inadequate calcium and vitamin D intake, high alcohol and caffeine intake, smoking, and low muscle mass) and non-modifiable factors (hereditariness, Caucasian ethnicity, age, female sex, hormonal status) (2,3). The risk of osteoporosis in women increases after menopause (1,4,5). Inadequate calcium intake and low serum 25 (OH) vitamin D_3 [$25(OH)D_3$] levels are important risk factors for osteoporosis because of increased bone turnover (6).

Caffeine intake may not harm human health unless the amount of consumption exceeds the safe limit (7). However,

high doses of caffeine may lead to damaging effects on bone metabolism, bone healing and osteoblastic activity (8). Caffeine can also reduce calcium absorption and increase its elimination (5). A study on postmenopausal women showed that high caffeine intake can increase lumbar bone loss (9). Another study reported that three or more cups consumption of coffee in a day may be a risk factor for osteoporosis (1). Nevertheless, the effect of caffeine consumption on bone metabolism is still controversial (10). This study aimed to evaluate the association between caffeine intake and bone density health among postmenopausal women with osteopenia or osteoporosis.

Methods

This single-center, cross-sectional study was conducted between May 2019 and December 2021 at Gaziler Hospital Physical Medicine and Rehabilitation Unit. Postmenopausal women aged between 41 and 65 years were included. Patients were excluded if they had secondary osteoporosis, diabetes mellitus, hyperthyroidism, primary hyperparathyroidism, hematologically or gastrointestinal disorders, and autoimmune diseases such as rheumatoid arthritis, ankylosing spondylitis, or renal diseases. Other exclusion criteria were the history of metabolic bone disease, regular use of vitamin D and/or calcium supplements, anti-acids with calcium; medications that influence bone mass (e.g., corticosteroids, thyroid hormone, lithium, heparin, furosemide and proton pump inhibitors), and smoking. All participants provided signed, informed consent. The study protocol was approved by the Gülhane Training and Research Hospital Ethics Committee (no: 19/197, date: 14.05.2019). All the study procedures followed the Declaration of Helsinki and the Uniform Requirements for articles submitted to biomedical journals.

Demographic and anthropometric data (body weight, height, hip, and waist circumferences) were collected. Body mass index was calculated as weight (kg)/height (m^2). The widest perimeter of the hip was recorded for hip circumference and the waist circumference was measured at 2-cm distal from the umbilicus. Serum $25(OH)D_3$ and serum total calcium levels were retrieved from the hospital registries.

Bone density assessment

Osteopenia or osteoporosis was diagnosed by DXA (Osteosys Primus device, Seoul, Korea). BMD results were classified according to Bone Health and Osteoporosis Foundation Guideline (11). BMD within 1.0 standard deviation (SD) of the mean for a young-adult reference population was classified as 'normal', BMD between 1.0 and 2.5 SD for a young-adult population was classified as 'osteopenia' and BMD 2.5 SD or more below the mean for a young-adult reference population was classified as 'osteoporosis'.

Nutritional evaluation

Two food frequency questionnaires (FFQ) were used in the study to evaluate food intake over the last month: FFQ for nutrient intake (including 42 foods and beverages), and a caffeine-specific FFQ to determine foods and beverages with caffeine content. The adequacy of nutrient intake was assessed according to age and gender using the Turkey Dietary Guidelines (12). The daily intake of macro- and micronutrients, and energy was calculated from the data obtained in the FFQ, using BeBiS software version 7.2 (Bebispro for Windows, 2010). In this study, the caffeine-containing food list used in the article by Işgın et al. (13) was updated and a caffeine-specific FFQ was applied. The consumption of 35 different foods and beverages (coffee, tea, cola, chocolate, etc.) with caffeine content was recorded. The following responses regarding the consumption frequency were used: never, once a month, twice a month, 1-2 times a week, 3-4 times a week, 5-6 times a week and every day. After obtaining data on the caffeine specific FFQ, a national study (14) and US Food Data Central (15) were used to detail how much caffeine each food and beverage contained, and the total caffeine intake was calculated. According to recent data (16), patients consuming more than 260 mg/day were classified as high consumers.

Assessment of physical activity

Physical activity level (PAL) was calculated by dividing the total (durations of activity in minutes multiplied by the physical activity ratio for each activity) by 1,440 min. The calculated PAL values were evaluated as follows: <1.40 sedentary, 1.40-1.69 light, 1.70-1.99 moderate, 2.00-2.40 heavy, >2.40 very heavy activity (17).

Statistical Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) for Mac, version 22.0 software (SPSS Inc., Chicago, IL, USA). Categorical variables are presented as numbers and percentages, and the numerical variables as mean and SD. The normality distribution was assessed using the Kolmogorov-Smirnov test. Categorical data were compared using the chi-square test, and continuous data were compared using the Student's t-test. Correlation coefficients were calculated using the Pearson's test. $P<0.05$ was accepted to be statistically significant.

Results

The study included 80 subjects (mean age: 57.1±5.6 years). Mean postmenopausal duration was 8.1±4.4 years. Table 1 shows the basic characteristics of the participants. No patient was underweight, 37.4% (n=30) were overweight and 26.4% (n=21) were obese. Most patients (40.0%, n=32) were graduates of university or higher. The mean PAL value was

1.3±1.1, and most patients were sedentary. When the patients were grouped as low or high consumers of caffeine, there was no statistically significant difference between these groups in terms of main characteristics.

The daily energy, nutrients, and caffeine intake of the participants are shown in Table 2. Mean caffeine intake was 229.7±119.5 mg, with 36.3% (n=29) as high consumers. There was no statistically significant difference between the high consumer and low consumer groups in terms of nutrient intake. Calcium intake was inadequate in 90.0% (n=72) of the patients.

Most patients had osteopenia (61.2% according to the lumbar spine total T-score and 66.3% according to the femoral neck T-score). Classification of the patients according to the lumbar total and femoral neck T-scores showed significant differences concerning the diagnosis of osteopenia or osteoporosis (p=0.013) (Table 3).

The mean total T-score was -1.42±0.89 at the lumbar spine and -1.69±0.87 at femoral neck. High and low caffeine consumers had similar mean total T-score at the lumbar spine (-1.4±1.1 vs. -1.4±0.8, p=0.849). However, femoral neck mean T-score was significantly lower in high caffeine consumers (-2.0±0.9 vs. -1.5±0.7, p=0.033).

While 84.3% of patients (n=43) had osteopenia, 15.7% of patients (n=8) had osteoporosis in low caffeine consumers. In high caffeine consumers, 58.6% of patients (n=17) had osteopenia, and 41.4% of patients (n=12) had osteoporosis. compared to low caffeine consumers, the percentage of patients with osteoporosis was significantly higher in high caffeine consumers (p=0.011).

A negative moderate correlation was determined between caffeine intake and the femoral neck T-score (Table 4). There was no correlation between total caffeine intake and the total T-score.

Table 1. Basic characteristics of the patients

Age, years, mean (SD)	57.1 (5.5)
Serum vitamin D (ng/mL), mean (SD)	26.9 (16.8)
Serum calcium (mg/dL), mean (SD)	10.5 (9.5)
Postmenopausal period (year), mean (SD)	8.1 (4.4)
BMI (kg/m^2), mean (SD)	27.1 (4.4)
Waist circumference (cm), mean (SD)	98.3 (10.8)
Hip circumference (cm), mean (SD)	106.1 (9.7)
Waist/hip ratio, mean (SD)	0.9 (0.05)
BMI classification	
Underweight, n (%)	-
Normal, n (%)	29 (36.3)
Overweight, n (%)	29 (36.3)
Obese, n (%)	21 (26.4)
Education	
Illiterate, n (%)	2 (2.5)
Primary school, n (%)	27 (33.8)
Secondary-high school, n (%)	18 (22.5)
University or Higher, n (%)	32 (40.0)
PAL classification	
Sedentary, n (%)	43 (53.8)
Light activity, n (%)	36 (45.0)
Moderate activity, n (%)	1 (1.2)
Heavy activity, n (%)	0 (0.0)
Very heavy activity, n (%)	0 (0.0)

SD: Standard deviation, BMI: Body mass index, PAL: Physical activity level

Discussion

The results of this study suggest that high caffeine intake deteriorates BMD in postmenopausal women, particularly in the femoral neck. Caffeine intake is widely common worldwide (18).

Table 2. Daily energy and nutrient intake

Caffeine (mg), mean (SD)	229.7 (119.5)
Total Energy intake [kcal], mean (SD)	1661.6 (388.2)
Carbohydrates [g/day], mean (SD)	150.5 (47.4)
Carbohydrates, n (%)	37.2 (7.4)
Protein [g/day], mean (SD)	66.5 (17.9)
Protein, n (%)	16.5 (2.5)
Fat [g/day], mean (SD)	86.2 (23.7)
Fat, n (%)	46.2 (6.6)
Cholesterol [mg/day], mean (SD)	313.8 (115.8)
Fiber [g/day], mean (SD)	20.0 (7.2)
Vitamin A, mean (SD)	1055.7 (867.9)
Vitamin C, mean (SD)	81.0 (40.2)
Vitamin E, mean (SD)	15.4 (6.5)
Calcium, mean (SD)	777.1 (272.0)
Phosphorus, mean (SD)	1189.7 (335.3)
Magnesium, mean (SD)	269.6 (86.8)

SD: Standard deviation

Table 3. The distribution of patients according to the lumbar total and femoral neck T-scores

	Lumbar total T-score		Femoral neck T-score		p*
	n	%	n	%	
Normal	20	25.0	13	16.3	
Osteopenia	49	61.2	53	66.3	0.013
Osteoporosis	11	13.8	14	17.4	

*Chi-square test

Table 4. Correlation between caffeine intake and total lumbar spine and femoral neck T-score

		Lumbar spine	Femoral neck
Caffeine	r	-0.12	-0.251
	p*	0.915	0.025

*Pearson test

Coffee, tea, energy drinks and many carbohydrated drinks, as well as cocoa, chocolate and some dietary supplements contain caffeine (19). Approximately 80% of adults consume at least one caffeine-containing beverage per day (20).

Caffeine consumption is classified as one of the modifiable risk factors for osteoporosis development (2). Reviews of the safe limits of caffeine consumption concluded that 200 mg in a single dose and 400 mg throughout the day should not be exceeded, and that caffeine will not cause harm when the consumption remains in the recommended range (21). In this study, the mean caffeine intake was 229.7±119.5 mg/d that is consistent with the previous data (22).

With respect to the clinical effects of caffeine intake on bones (e.g., BMD loss, fractures), previous research findings are inconsistent. Hallström et al. (5) reported a small reduction in bone density with caffeine intake but no increase in the risk of new fractures. Harter et al. (23) found no association between caffeine intake and calcium intake and bone mass. In contrast, in a meta-analysis by Lee et al. (24), a positive dose-dependent association between caffeine and fracture formation among women was reported. De França et al. (25) investigated the dietary patterns in postmenopausal Brazilian women and observed an inverse relationship between coffee, tea, sweet food consumption and total femoral BMD.

Correlation analysis in the current study showed that the femoral neck T-score but not the lumbar spine T-score was inversely related to the amount of caffeine intake. The differences in T-scores between the BMD measurement sites might have influenced the correlation analyses. Because, differences are common between the BMD measurement sites. Alarkawi et al. (26) reported lower lumbar spine BMD than the femoral neck BMD. Rochmis et al. (27) also reported discordance between the femoral total and femoral neck BMD measurements. Further studies are necessary to explain the exact reason for the site-specific relationship between caffeine intake and BMD.

In this study, 36.3% of the patients who were classified as high consumers, and the femoral total T-score among high consumers was lower than those of the low consumers. This result was in concordance with the correlation analysis, which showed an inverse relationship with caffeine intake. Similarly, Hallström et al. (5) investigated the effect of long-term caffeine consumption on BMD and fracture risk. When the high consumers (≥4 cups) were compared with low consumers (≤1 cup), high coffee intake was associated with 2% lower BMD in proximal femoral BMD and 4% in the lumbar spine.

Concerns related to the correct assessment of caffeine intake have been discussed previously (23). Issues of objectivity occur due to biased methods reliant on patient reports (16). In this study, dietary assessment and caffeine intake were assessed using the FFQ administered by a registered dietician to optimize the method of evaluation of the amount of caffeine intake. In addition to the measurement method of caffeine intake, differences in the metabolism and absorption of caffeine between individuals can change the biological effects of caffeine (28). As can be seen in the results section, the percentage of adequate calcium intake was very low. Calcium is bound to collagen fibers in the form of hydroxyapatite and is essential for bone strength. Low calcium intake has been identified as a risk factor for developing osteoporosis (29). High calcium intake can improve bone mineral content and thus reduce the risk of fractures in menopause (30). However, it should be remembered that taking calcium alone is not enough to reduce the risk of new fractures in the postmenopausal period, and it should be taken with 25(OH)D_3 (31).

There are some limitations of this study, such as the relatively small sample size and lack of longitudinal follow-up. The use of T-scores and the lack of bone density values may also be a limitation as the calculation of T-scores consider additional parameters. Finally, we could not perform adjusted analysis due to small sample size. The major strength of this study was that the food consumption records were taken directly by an experienced dietician.

Conclusion

The results of this study suggest that higher caffeine intake may be associated lower T-scores on DXA of the femoral neck.

Ethics

Ethics Committee Approval: The study protocol was approved by the Gülhane Training and Research Hospital Ethics Committee (no: 19/197, date: 14.05.2019).

Informed Consent: All participants provided signed, informed consent.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices - Concept - Design - Data Collection or Processing - Analysis or Interpretation - Literature Search - Writing: K.T.A., Ö.K.

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References

1. Bijelic R, Milicevic S, Balaban J. Risk factors for osteoporosis in postmenopausal women. Med Arch. 2017;71:25-28.
2. Kanis JA, Johnell O, Oden A, Jonsson B, De Laet C, Dawson A. Risk of hip fracture according to the World Health Organization criteria for osteopenia and osteoporosis. Bone. 2000;27:585-590.
3. Pouresmaeili F, Kamalidehghan B, Kamarehei M, Goh YM. A comprehensive overview on osteoporosis and its risk factors. Ther Clin Risk Manag. 2018;14:2029-2049.
4. Weaver CM, Gordon CM, Janz KF, et al. The National Osteoporosis Foundation's position statement on peak bone mass development and lifestyle factors: a systematic review and implementation recommendations. Osteoporos Int. 2016;27:1281-1386.
5. Hallström H, Byberg L, Glynn A, Lemming EW, Wolk A, Michaëlsson K. Long-term coffee consumption in relation to fracture risk and bone mineral density in women. Am J Epidemiol. 2013;178:898-909.
6. Garnero P, Munoz F, Sornay-Rendu E, Delmas PD. Associations of vitamin D status with bone mineral density, bone turnover, bone loss and fracture risk in healthy postmenopausal women. The OFELY study. Bone. 2007;40:716-722.
7. Mitchell DC, Knight CA, Hockenberry J, Teplansky R, Hartman TJ. Beverage caffeine intakes in the U.S. Food Chem Toxicol. 2014;63:136-142.
8. Berman NK, Honig S, Cronstein BN, Pillinger MH. The effects of caffeine on bone mineral density and fracture risk. Osteoporos Int. 2022;22:1235-1241.
9. Rapuri PB, Gallagher JC, Kinyamu HK, Ryschon KL. Caffeine intake increases the rate of bone loss in elderly women and interacts with vitamin D receptor genotypes. Am J Clin Nutr. 2001;74:694-700.
10. Li S, Dai Z, Wu Q. Effect of coffee intake on hip fracture: a meta-analysis of prospective cohort studies. Nutr J. 2015;14:38.
11. Leboff MS, Greenspan SL, Insogna KL, Lewiecki EM, Saag KG, Singer AJ, Siris ES. The clinician's guide to prevention and treatment of osteoporosis. Osteoporos Int. 2022. doi:10.1007/s00198-021-05900-y.
12. Türkiye Beslenme Rehberi. Last Accessed Date: 11.04.2022. Available from: https://hsgm.saglik.gov.tr/depo/birimler/saglikli-beslenme-hareketli-hayat-db/Yayinlar/rehberler/2015-beslenme-rehberi.pdf
13. Işgın K, Kabasakal Çetin A, Yiğit M, Büyüktuncer Z, Besler HT, Gökmen Özel H. Adolesanlarda kafein içeren yiyecek ve içecek tüketimi üzerine bir araştırma. Beslenme ve Diyet Dergisi. 2015;2:119-125.
14. Hancı M, Bayram S, Karahan S, Kaya E, Bakırcı S. Caffeine Levels in Turkish Coffee and Some Beverages Sold in Turkey. Duzce Med J. 2013;15:34-38.
15. U.S. Department of Agriculture, Agricultural Research Service. FoodData Central, 2019. Last Accessed Date: 10.04.2022. Available from: fdc.nal.usda.gov.
16. Berman NK, Honig S, Cronstein BN, Pillinger MH. The effects of caffeine on bone mineral density and fracture risk. Osteoporos Int. 2022;33:1235-1241.
17. Food and Agriculture Organization. Food and Nutrition Technical Report Series. Human energy requirements. Last accessed date: 11.03.2022. Available from: https://www.fao.org/3/y5686e/y5686e.pdf
18. O'Callaghan F, Muurlink O, Reid N. Effects of caffeine on sleep quality and daytime functioning. Risk Manag Healthc Policy. 2018;11:263-271.
19. Barone JJ, Roberts HR. Caffeine consumption. Food Chem Toxicol. 1996;34:119-129.
20. Ogawa N, Ueki H. Clinical importance of caffeine dependence and abuse. Psychiatry Clin Neurosci. 2007;61:263-268.
21. Scientific Opinion on the safety of caffeine. EFSA J. 2015;13:4102.
22. Hansen SA, Folsom AR, Kushi LH, Sellers TA. Association of fractures with caffeine and alcohol in postmenopausal women: the Iowa Women's Health Study. Public Health Nutr. 2000;3:253-261.
23. Harter DL, Busnello FM, Dibi RP, Stein AT, Kato SK, Vanin CM. Association between low bone mass and calcium and caffeine intake among perimenopausal women in Southern Brazil: cross-sectional study. Sao Paulo Med J. 2013;131:315-322.
24. Lee DR, Lee J, Rota M, et al. Coffee consumption and risk of fractures: a systematic review and dose-response meta-analysis. Bone. 2014;63:20-28.
25. de França NA, Camargo MB, Lazaretti-Castro M, Peters BS, Martini LA. Dietary patterns and bone mineral density in Brazilian postmenopausal women with osteoporosis: a cross-sectional study. Eur J Clin Nutr. 2016;70:85-90.
26. Alarkawi D, Bliuc D, Nguyen TV, Eisman JA, Center JR. Contribution of lumbar spine BMD to fracture risk in individuals with T-score discordance. J Bone Miner Res. 2016;31:274-280.
27. Rochmis PG, Sheridan MJ, Perry L. Is the NHANES III femoral neck database discordant with the total hip and trochanteric region databases? J Clin Densitom. 2009;12:224-228.
28. Institute of Medicine, Food and Nutrition Board, Committee on Military Nutrition Research. Caffeine for the Sustainment of Mental Task Performance: Formulations for Military Operations. 1st ed. Washington (DC): National Academies Press; 2001

29. Rizzoli R, Bischoff-Ferrari H, Dawson-Hughes B, Weaver C. Nutrition and bone health in women after the menopause. Womens Health (Lond). 2014;10:599-608.

30. Bonjour JP, Benoit V, Rousseau B, Souberbielle JC. Consumption of vitamin D-and calcium-fortified soft white cheese lowers the biochemical marker of bone resorption TRAP 5b in postmenopausal women at moderate risk of osteoporosis fracture. J Nutr. 2012;142:698-703.

31. Bischoff-Ferrari HA, Dawson-Hughes B, Baron JA, et al. Calcium intake and hip fracture risk in men and women: a meta-analysis of prospective cohort studies and randomized controlled trials. Am J Clin Nutr. 2007;86:1780-1790.