Caffeine Effect on Bone Mineral Density: A Cross-sectional Study

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ABSTRACT

Introduction: Osteoporosis is a serious disease of bone, all elderly people and post menopausal women will eventually experience it in their lives. Recent studies have shown that caffeine has a negative effect on Bone Mineral Density (BMD) by accelerating osteoporosis through different mechanisms.

Aim: To determine the relationship between caffeine intake from different sources (arabic coffee, black tea and green tea) collectively and the effect of each one of these sources separately on the BMD.

Materials and Methods: The present cross-sectional study was conducted from October 2014 to 2015 that included men and post menopausal women above the age of 50 years. Osteoporosis risk factors were evaluated through a questionnaire that was constructed by our team and the daily amount of caffeine consumed was estimated. Information about calcium and vitamin D intake was also collected as they play an important role in maintaining bone health. All the patients underwent Dual-energy X-ray Absorptiometry (DXA) scan. SPSS statistics software was used for data analysis.

Results: A total of 250 subjects participated in the study, with only 22 (8.8%) male subjects. The mean age was 65 years and 125 (50%) of the patients were diagnosed with osteopenia, 80 (32%) had osteoporosis, and 45 (18%) had normal BMD. The total estimated daily caffeine intake was 186 mg/day.

Osteoporotic group showed to have non significantly higher calcium/vitamin D intake and was more likely to report sedentary lifestyle and had fragility fractures.

Osteoporotic group reported to have non significantly higher caffeine intake mainly from arabic coffee and black tea, but lower caffeine from green tea when compared to the osteopenic group. Adjusting for possible confounding factors, a non significant negative partial correlation was found between total caffeine intake and L-spine BMD, and between caffeine from black tea and femoral neck BMD. Also, a non significant positive partial correlation was observed between total caffeine and femoral neck BMD, and between caffeine from black tea and L-spine BMD, and between caffeine from green tea and arabic coffee and both L-spine and femoral neck BMD.

Conclusion: According to the results of the present study it was observed that there is no significant correlation between BMD and daily caffeine consumption and therefore we may conclude that there is no relationship between osteoporosis and caffeine consumption.

INTRODUCTION

Osteoporosis and osteopenia are two medical terms used to describe the deterioration in bone density when assessed by DXA scan. Both have similar causes and risk factors, in fact osteopenia is the stage preceding osteoporosis and it's described as T-score in the DXA scan between -1 to -2.4 and osteoporosis is defined as T-score of < -2.5 [1,2]. Osteoporotic bone is fragile, that is more liable to fracture and it's caused by increasing osteoclast activity and decreasing osteoblast activity [3,4]. The activities of the osteoblast and osteoclast cells are influenced by many factors like parathyroid hormone, oestrogen, growth factors, calcitonin and cytokines [5-9]. Osteoporosis can affect primarily the elderly (senile osteoporosis), or post menopausal women (post menopausal osteoporosis), or it can be secondary to well-defined illnesses like Cushing's syndrome, rheumatoid arthritis, and thyrotoxicosis and in this case it's called secondary osteoporosis [10].

Caffeine is a substance that can be considered as a drug, it is found in coffee, tea, cola, and cacao [11]. Calcium is one of the most critical elements in the human body with more than 99% of the body calcium present in bones. Calcium has many essential roles in the body like supporting bones [12]. Vitamin D has multiple important functions in the body like maintaining bone health and calcium homeostasis by stimulating calcium and phosphate absorption from the intestine, mobilisation of calcium from the bone and calcium reabsorption from the kidney [13]. Research showed that caffeine can increase calcium excretion by kidneys and it can stimulate alkaline phosphatase activity on osteoblasts, as well as reduce vitamin D function [14,15].

Relationship between caffeine and bone density and risk of future fractures have been assessed in previous published studies, most of these studies focussed on caffeine effect on BMD of post menopausal and elderly women, for example a Swedish cohort study assessed coffee consumption through food frequency questionnaire and measured BMD for 61,433 women born between 1914 to 1948, the study found that high consumption of coffee was associated with minimal reduction in BMD but it's not going to increase the risk of fracture [16], their conclusion was similar to that of a Norwegian study which concluded that caffeine has weak adverse effect on BMD, this study used a self-administered questionnaire with Single energy X-ray Absorptiometry (SXA) to study the relationship between caffeine and BMD in post menopausal women [17]. Furthermore, a cross-sectional study examined the impact of total caffeine intake from coffee, on bone mass loss in post menopausal women, it showed that high caffeine intake (>300 mg/day) accelerated bone loss at the spine [18].

Most of published research studied the effect of caffeine on BMD from coffee and tea, but when it comes to caffeine consumed from arabic coffee there is limited national data and no international data at all about its impact on BMD, so the primary outcome of the study was to assess the relationship between amount of caffeine

consumption from different sources (arabic coffee, black tea and green tea) and the prevalence of osteopenia and osteoporosis. In addition, the study evaluated the impact of the caffeine source on BMD. We also evaluated the impacts of other related risk factors including the age, sex, smoking, passive smoking, history and diagnosis of previous fracture, and corticosteroids use and its route of administration on BMD.

MATERIALS AND METHODS

The present cross-sectional study was conducted at Prince Mansour Military Hospital in Saudi Arabia between October 2014 to 2015. Study was approved by Prince Mansour Military Hospital Institutional Review Board. The BMD test was done for each patient by a certified nurse under supervision of a certified clinical densitometrist at the time of their regular clinic visit.

The personal information was collected through an interview and a questionnaire. The questionnaire included questions related to the major factors affecting bone health, it included lifestyle and diet related questions (if they exercise or not, the frequency, duration and type of exercise, and if they smoke or not, if they drink milk or eat yogurt and the number of cups they drink/eat every day, and if they take any calcium or vitamin D supplementations), it also included questions regarding the use of medications like hormonal replacement therapy, oestrogen pills, oral contraceptive pills and corticosteroids and the route for corticosteroid usage (pills, injections or by inhalation) with questions about previous history of fractures and the cause of it/them. Additional questions for our female patients: number of pregnancies, age at first pregnancy and last pregnancy.

The dietary and supplemental intake of calcium and vitamin D was collected and calculated per day. Data about the physical activities and hormonal replacement therapy were self- reported. We also evaluated the common source for calcium intake in the patients. The amount of calcium estimated from the nutritional facts label of local milk and dairy products, for each cup of milk/day was 200 mg, 300 mg for 1 cup of yogurt/day and 600 mg of calcium for 1 tablet or 1 dose of calcium syrup. The researchers sat with the respondents, explained the rationale of the study and the process and took an informed consent from them. The questionnaire was filled immediately by the researchers.

We included post menopausal women and men above the age of 50 years who were willing to participate in the study. We excluded patients with end-stage renal disease, hyperthyroidism, hyperparathyroidism, Cushing's syndrome, men below the age of 50 years, and pre menopausal woman. Height and weight were measured at the time of the visit and the Body Mass Index (BMI) was calculated for each patient.

Parental history of hip fractures was collected and Fracture Risk Assessment Tool (FRAX) score was calculated by filling a questionnaire found on the university of Sheffield website for fracture risk assessment [19]. To fill this questionnaire we used the following information (age, sex, weight, height, previous fractures, parental history of hip fracture, current smoking, glucocorticoid use, history of rheumatoid arthritis, alcohol consumption, history of secondary osteoporosis, and we used the BMD we measured to fill the questionnaire. FRAX score was used for assessing the patient's risk of having a fracture secondary to osteoporosis within 10 years.

We inquired about the commonly consumed caffeine in Saudi Arabia, which includes the arabic coffee, black tea, and green tea. The amount of habitual daily caffeine intake was estimated by evaluating the average number of cups consumed daily for different caffeine containing beverages, and estimating the average amount of caffeine in each type of beverage and the total intake was calculated, in case patient consumed it from more than one source. The amount of caffeine per cup for the arabic coffee was 40 mg/cup, for black tea was 14 mg/cup, and for green tea was 24 mg/cup.

STATISTICAL ANALYSIS

Data were collected and analysed using the Statistical Package for the Social Sciences (SPSS) software version 20.0. Frequencies and percentages were used for each variable. The Chi-square test was used to study the relationship between variables and the T-test was used to compare between means. Partial correlation analysis was used to determine the degree of association between BMD and caffeine intake.

RESULTS

A total of 250 patients participated in the study. The mean±SD age was 65.71±9.85 years with female predominance. The mean weight was 77.11±14.76 kg; most of the patients were obese with a mean BMI of 32.58±5.57 kg/m². Of the total 146 (58.4%) of the patients reported sedentary lifestyle. Only two men and two women were active smokers, eight women were on hormonal replacement therapy and 19 patients were using corticosteroids regularly [Table/Fig-1].

Baseline characteristics	
Mean age (years)	65.71±9.85
Male (%)	22 (8.8)
Female (%)	228 (91.2)
Mean±SD weight (kg)	77.11±14.76
Mean±SD BMI (kg/m²)	32.58±5.57
Osteopenia (%)	125 (50)
Osteoporosis (%)	80 (32)
Mean±SD femur neck bone mineral density (gm/cm²)	0.884±0.181
Mean±SD lumber spine bone mineral density (gm/cm²)	0.970±0.56
Mean±SD calcium intake (mg/day)	551.41±354.02
Sedentary lifestyle (%)	146 (58.4)
Active smokers (%)	4 (1.6)
History of previous personal fracture (%)	52 (20.8)
Fragility fracture in those who experienced fractures (%)	33 (13.2)
Women who are taking hormonal replacement therapy (%)	8 (3.2)
Patients who are taking vitamin D supplementations (%)	142 (56.7)
Patients who are taking corticosteroids regularly (%)	19 (7.6)
Parental history of hip fracture (%)	4 (1.6)
Mean±SD Vitamin D 25-OH level (ng/mL)	19.92±10.66
Caffeine Intake	**Mean±SD**
Total caffeine intake (mg/day)	186.2±241.97
Arabic coffee intake (cup/day)	4.43±6.1
Caffeine from arabic coffee (mg/day)	178.2±245.1
Green tea intake (cup/day)	1.31±0.72
Caffeine from green tea (mg/day)	31.56±18.18
Black tea intake (cup/day)	2.36±1.93
Caffeine from black tea (mg/day)	33.18±26.92

[Table/Fig-1]: Baseline characteristics of the whole cohort.

Of the total 142 (56.7%) of the patients were on vitamin D supplementation with the mean vitamin D 25-OH level 19.92±10.66 ng/mL. The mean daily intake of calcium was estimated as 551.41±354.02 mg/day. Women who were on hormonal replacement therapy were more likely to have osteopenia. Of the total 52 (21%) of the patients had history of previous fracture and 13.2% of these patients had fragility fractures. Only four patients among the entire sample had parental history of hip fracture. The mean

BMD of femur neck bone marrow was 0.884±0.181 g/cm², while the mean density of lumber spine bone marrow was 0.970±0.56 g/cm². We divided our patients into two groups based on their DXA scan result. Of the total 125 (50%) of the patients were diagnosed with osteopenia, 80 (32%) had osteoporosis, and 45 (18%) had normal BMD. Compared to the group of osteopenia, those with osteoporosis were significantly older in age and more likely to be females, with lower BMI and lower weight. The osteoporosis group had slightly higher level of calcium and vitamin D, and reported higher calcium intake and vitamin D intake. They were more likely to be active smokers, and reported sedentary lifestyle, with history of previous fracture, particularly fragility fracture, but none of these findings was statistically significant. On the other hand, the subjects in osteopenia group were more likely to be passive smokers with parental history of hip fracture. The amount of caffeine intake was compared between the groups and the results showed no statistical differences between them [Table/Fig-2]. Partial correlation adjusted for BMI, exercise, active smoking, passive smoking, taking vitamin D supplements, corticosteroids use, oestrogen replacement, daily calcium intake and the vitamin D level showed a negative partial correlation between total caffeine intake and L-spine BMD, positive partial correlation between total caffeine and femoral neck

BMD, positive partial correlation between caffeine from black tea and L-spine BMD, negative partial correlation between caffeine from black tea and femoral neck BMD, positive partial correlation between caffeine from green tea and L-spine BMD, positive partial correlation between caffeine from green tea and femoral neck BMD, positive partial correlation between caffeine from arabic coffee and L-spine BMD, and positive partial correlation between caffeine from arabic coffee and femoral neck BMD [Table/Fig-3].

	L-Spine BMD	Femoral Neck BMD
Total Caffeine	r=−0.054	r=0.58
	p=0.387	p=0.247
Black tea	r=0.42	r=−0.045
	p=0.364	p=0.353
Green tea	r=0.227	r=0.131
	p=0.123	p=0.254
Arabic coffee	r=0.129	r=0.158
	p=0.438	p=0.345

[Table/Fig-3]: Partial correlation adjusted for BMI, exercise, active smoking, passive smoking, taking vitamin D supplements, corticosteroids use, oestrogen replacement use, daily calcium intake and the vitamin D level.
BMD-Bone Mineral Density

	Osteopenia n=125	Osteoporosis n=80	p-value
Baseline characteristic			
Mean age (years)	64.72±9.2	69.33±9.15	0.001
Male (%)	7 (5.6)	4 (5)	0.001
Female (%)	117 (93.7)	77 (96.25)	
Mean weight (kg)	78.04±13.11	71.36±13.32	0.000
Mean BMI (kg/m²)	33.2±5.3	30.7±5.3	0.001
Mean femur neck BMD (g/cm²)	0.888±0.192	0.793±0.118	0.000
Mean lumber spine BMD (g/cm²)	1.026±0.764	0.797±0.123	0.008
Mean calcium intake (mg/day)	539.1±357.4	580.1±366.96	0.446
Sedentary lifestyle (%)	71 (56.8)	51 (63.8)	0.590
Active smokers (%)	1 (0.8)	2 (2.5)	0.616
Passive smokers (%)	23 (18.4)	12 (15)	0.341
History of personal fracture (%)	27 (21.6)	19 (23.8)	0.274
Women on hormonal replacement therapy (%)	4 (3.2)	2 (2.5)	0.831
Patients taking vitamin D (%)	70 (56)	48 (60)	0.742
Patients taking corticosteroids regularly (%)	7 (5.6)	7 (8.75)	0.394
Parental history of hip fracture (%)	2 (1.6)	1 (1.2)	0.888
Mean vitamin D 25-OH level (ng/mL)	19.9±11.3	20.1±10.3	0.934
Caffeine intake (mean±SD)			
Total caffeine intake (mg/day)	160.2±182.3	185.6±221.1	0.407
Arabic coffee intake (cup/day)	3.7±4.7	4.4±5.3	0.401
Caffeine from arabic coffee (mg/day)	148.6±189.3	173.6±212.9	0.447
Green tea intake (cup/day)	1.4±0.8	1.2±0.7	0.637
Caffeine from green tea (mg/day)	33.2±20.5	29.7±15.9	0.112
Black tea intake (cup/day)	2.4±1.9	2.4±2.1	0.849
Caffeine from black tea (mg/day)	33.2±26.5	34.1±29.8	0.850

[Table/Fig-2]: Baseline characteristics based on whether patients have osteoporosis or osteopenia.

DISCUSSION

Our results showed that there was no significant effect of caffeine on bone health; although, the daily caffeine intake of those who were diagnosed with osteoporosis was greater than the daily intake of osteopenic patients. A Swedish cohort study that included 61,433 old post menopausal women with a follow up of 21 years concluded that high or low coffee intake was associated with 2%-4% lower BMD depending on the measured site [16]. This study used a different study design, single different source of caffeine, focussed only on women, and the sample size was greater than our sample size.

Another Norwegian study used the data from a previous osteoporosis study done in Oslo including 695 old women, collected the dietary information through self-administered questionnaire, and estimated the amount of caffeine consumption from coffee and caffeinated soft drinks, and estimated calcium intake from different sources like milk, yoghurt and cheese, then measured the BMD of distal forearms using SXA and concluded that caffeine has a negative effect on BMD [17]. The differences between this study and our study lies in many aspects: such that they estimated caffeine intake from coffee and soft drinks, soft drinks were not included in our study, they estimated amount of calcium intake from cheese, we asked about cheese intake but we didn't consider it as an important source of calcium for our patients, lastly they used SXA, a different method for measuring BMD of the distal forearm and we used DXA to measure the BMD of lumbar spine and neck of femur, according to data SXA and DXA differ in precision [20]. Another study that support our findings is a cross-sectional study focussed on younger women between the ages of 19-26 years, who attended the Midwestern University, they assessed the average daily intake of caffeine from coffee, tea, chocolate products and colas, additional to that they assessed the daily intake of decaffeinated coffee, measured the femoral neck BMD and lumber spine BMD [21]. They showed that for every 100 mg of caffeine there's a slight reduction in lumbar spine BMD and femoral neck BMD but generally caffeine is not a risk factor in young women for low BMD.

The lack of statistical significance in our study may be due to the nature of caffeine in our population or the amount of caffeine consumed. A daily intake of more than 300 mg of caffeine can accelerate bone loss in post menopausal women according to a recent study [18].

Our study shows that there might be a weak positive effect of black tea on lumber spine BMD and negative effect on femoral

neck BMD, when compared to literature, research suggests that black tea intake has a positive effect on BMD as it improves bone health and protects against bone loss and osteoporosis [22,23]. One study showed that drinking four or more cups of black tea daily can significantly increase total body BMD when compared to non daily tea drinkers but no significant association was found between drinking tea and lumber spine or hip BMD [24].

When it comes to green tea we found that it has a minimal positive influence on BMD of lumber spine and femoral neck. Green tea has anti-inflammatory and antioxidant properties [25]. A Japanese study also supports our finding by concluding that the BMD of green tea drinkers is better than the BMD of those who don't drink it [26]. Surprisingly, we found that arabic coffee may have a positive effect on lumber spine and femoral neck BMD and the only explanation we can think of is, it may contain some bioactive substances that are beneficial to bone health. Unfortunately, there is no adequate scientific information regarding arabic coffee effect on BMD, however a Korean study on post menopausal women had found that coffee drinking effect is directly correlated to BMD, perhaps they may have used similar ingredients as in arabic coffee [27].

LIMITATION
Our study weakness includes the small sample size, female predominance and the single center. We recommend future study using prospective study designs, a larger population, multicenter, and with an adequate number of male patients.

CONCLUSION
The findings of the present study showed that those with osteoporosis consumed higher total caffeine, mainly from arabic coffee. Also, it was shown that green tea was associated with lesser potential effect on BMD.

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