

# Tea drinking and bone mineral density in older women<sup>1-3</sup>

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## ABSTRACT

**Background:** High caffeine intake is reportedly a risk factor for reduced bone mineral density (BMD) in women. Most studies, however, are from populations in which coffee drinking predominates and is the major caffeine source. Tea contains caffeine but also has other nutrients, such as flavonoids, that may influence bone mass in different ways.

**Objective:** We examined the relation between tea drinking and BMD in older women in Britain, where tea drinking is common.

**Methods:** We measured BMD at the lumbar spine, femoral neck, greater trochanter, and Ward's triangle in 1256 free-living women aged 65–76 y in Cambridge, United Kingdom. Tea drinking was assessed by self-completed questionnaire and women were categorized as tea drinkers or non-tea drinkers.

**Results:** There were 1134 tea drinkers (90.3%) and 122 non-tea drinkers (9.7%). Compared with non-tea drinkers, tea drinkers had significantly greater ( $\approx 5\%$ ) mean BMD measurements, adjusted for age and body mass index, at the lumbar spine ( $0.033 \text{ g/cm}^2$ ;  $P = 0.03$ ), greater trochanter ( $0.028 \text{ g/cm}^2$ ;  $P = 0.004$ ), and Ward's triangle ( $0.025 \text{ g/cm}^2$ ;  $P = 0.02$ ). Differences at the femoral neck ( $0.013 \text{ g/cm}^2$ ) were not significant. These findings were independent of smoking status, use of hormone replacement therapy, coffee drinking, and whether milk was added to tea.

**Conclusions:** Older women who drank tea had higher BMD measurements than did those who did not drink tea. Nutrients found in tea, such as flavonoids, may influence BMD. Tea drinking may protect against osteoporosis in older women. *Am J Clin Nutr* 2000;71:1003–7.

**KEY WORDS** Tea, bone mineral density, flavonoids, hormone replacement therapy, osteoporosis, women, United Kingdom

## INTRODUCTION

Fractures (in particular, hip fractures) are a leading cause of ill health in older men and women. Although many risk factors have been documented for hip fractures (1, 2), osteoporosis, or low bone mineral density (BMD), is the single most important known risk factor for fractures in older women (1).

Lifestyle characteristics that influence BMD have been reported, including physical activity (2), smoking (3), and excessive alcohol intake (4). These factors are also associated with risk of hip fracture (5). Dietary calcium supplementation was shown to positively affect BMD in postmenopausal women (5) and caffeine intake was negatively associated with BMD in this group (6–9). The studies on caffeine intake and BMD were car-

ried out in communities in which most caffeine intake was in the form of coffee. Although caffeine is also found in tea, the relation between tea drinking and BMD is not clear. Tea contains a different pattern of nutrients (eg, flavonoids) than does coffee, which may have other potential effects on bone. Indeed, tea was reported to protect against hip fractures (10, 11); the researchers suggested that this might be explained by components in tea such as phytoestrogens or fluoride, which may influence BMD. Tea drinking is particularly common in Britain and the present cross-sectional study examined the relation between tea drinking and BMD in older British women.

## SUBJECTS AND METHODS

Women were recruited as part of a community-based health and BMD study conducted between 1991 and 1995. All women aged 65–76 y on the population age-sex registers of participating general practices in Cambridge, United Kingdom, were sent letters informing them of the study. Selection was not based on health status. Approximately half of the women who were contacted agreed to participate in the study. Each woman completed a questionnaire about health and lifestyle characteristics that included questions on daily tea and coffee intake. Participants attended the Bone Density Unit at Addenbrooke's Hospital, Cambridge. Height and weight were measured by trained observers and body mass index (BMI; in  $\text{kg/m}^2$ ) was calculated. The protocol was approved by the Cambridge Health Authority.

### Tea drinking

The women were asked separate questions about tea and coffee drinking and were categorized as tea drinkers or non-tea drinkers on the basis of self-report; the tea drinkers were further categorized as drinking 1–3 cups, 4–6 cups, or >6 cups/d. The tea drinkers were also categorized as adding or not adding milk to their tea. Tea drinkers and non-tea drinkers were further subdivided into those who did and those who did not drink coffee.

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**TABLE 1**

Descriptive characteristics of 1256 women aged 65–76 y according to self-reported tea drinking<sup>1</sup>

	Non-tea drinkers (n = 122)	Tea drinkers (n = 1134)
Age (y)	69.5 ± 2.7 <sup>2</sup>	69.8 ± 2.7
BMI (kg/m <sup>2</sup> )	26.3 ± 4.4	25.9 ± 3.9
Smoking status <sup>3</sup>		
Never smoker (%)	53.2	53.5
Exsmoker (%)	31.9	36.9
Current smoker (%)	13.1	8.4
Current users of hormone replacement therapy (%) <sup>4</sup>	6.5	3.9

<sup>1</sup>There were no significant differences between groups.

<sup>2</sup> $\bar{x} \pm SD$ .

<sup>3</sup>n = 65 non-tea drinkers and 607 tea drinkers who were never smokers, 39 non-tea drinkers and 419 tea drinkers who were exsmokers, and 16 non-tea drinkers and 95 tea drinkers who were current smokers.

<sup>4</sup>n = 8 non-tea drinkers and 44 tea drinkers.

### Bone mineral density measurements

BMD was measured at the lumbar spine (L234) and at the hip (femoral neck, greater trochanter, and Ward's triangle) by dual-energy X-ray absorptiometry with the Hologic QDR-1000 instrument (Hologic Inc, Waltham, MA). The measurements were expressed as area density (in g/cm<sup>2</sup>). Precision for in vivo measurements was 1.0% for the spine and 1.5–3.0% for the hip (12).

### Other variables

Participants were categorized according to smoking status as never smokers, exsmokers, or current smokers. Coffee drinkers were categorized as to whether they drank caffeinated or decaffeinated coffee (instant or ground). Each woman also answered a question about current use of hormone replacement therapy.

### Statistical analysis

Statistical analyses were performed by using SPSS (SPSS Inc, Chicago) on the mainframe computer at the University of Cambridge. Two-sided tests were used and the level of significance was set at 0.05. Crude, age-adjusted, and age- and BMI-adjusted mean BMD measurements were compared by using analysis of variance.

## RESULTS

We present results for 1256 women aged 65–76 y, of whom 1134 (90.3%) were tea drinkers and 122 (9.7%) were non-tea drinkers. The characteristics of the tea drinkers and the non-tea drinkers are shown in **Table 1**. The 2 groups were similar with respect to mean age and BMI. A slightly higher percentage of the non-tea drinkers were current smokers and current users of hormone replacement therapy, although the differences were not significant.

### Tea drinkers compared with non-tea drinkers

The crude, age-adjusted, and age- and BMI-adjusted mean BMD measurements at the spine and hip in tea drinkers and non-tea drinkers are shown in **Table 2**. Age- and BMI-adjusted mean BMD at the lumbar spine, greater trochanter, and Ward's triangle were significantly higher in tea drinkers than in non-tea

drinkers. This trend was also noted, but was not significant, for BMD measured at the femoral neck.

### Number of cups of tea per day

Overall, mean BMD measurements at selected sites were higher in tea drinkers than in non-tea drinkers. However, there was no significant trend according to the reported daily number of cups of tea (**Table 3**).

### Addition of milk to tea

Mean age- and BMI-adjusted BMD measurements at the lumbar spine, femoral neck, and Ward's triangle were similar in women who did not add milk to their tea and those who did add milk (**Table 3**). Women who added milk to their tea had significantly higher mean BMD measured at the greater trochanter than did those who did not add milk to their tea or non-tea drinkers.

### Coffee drinking

Self-reported coffee drinking was not related to BMD at any site. Among coffee drinkers (n = 1025), those who drank tea had significantly higher age- and BMI-adjusted mean BMD measurements at the lumbar spine, greater trochanter, and Ward's triangle. Differences at the femoral neck were also consistent, although not significant. Among non-coffee drinkers (n = 231), trends were similar but differences in BMD between tea drinkers and non-tea drinkers were not significant given the small samples. There was no significant interaction between tea drinking and coffee drinking.

### Smoking and hormone replacement therapy

When the analysis was repeated after current smokers and women currently receiving hormone replacement therapy were

**TABLE 2**

Crude, age-adjusted, and age- and BMI-adjusted mean bone mineral density at selected sites in 1256 women aged 65–76 y according to self-reported tea drinking

	Bone mineral density	
	Non-tea drinkers (n = 122)	Tea drinkers (n = 1134)
	g/cm <sup>2</sup>	
Lumbar spine		
Crude	0.889 ± 0.16 <sup>1</sup>	0.917 ± 0.17
Age-adjusted	0.889	0.917
Age- and BMI-adjusted	0.886	0.919 <sup>2</sup>
Femoral neck		
Crude	0.660 ± 0.10	0.669 ± 0.11
Age-adjusted	0.660	0.670
Age- and BMI-adjusted	0.658	0.671
Greater trochanter		
Crude	0.588 ± 0.09	0.612 ± 0.15 <sup>3</sup>
Age-adjusted	0.588	0.612 <sup>3</sup>
Age- and BMI-adjusted	0.586	0.614 <sup>4</sup>
Ward's triangle		
Crude	0.454 ± 0.12	0.476 ± 0.13
Age-adjusted	0.455	0.475 <sup>5</sup>
Age- and BMI-adjusted	0.452	0.477 <sup>3</sup>

<sup>1</sup> $\bar{x} \pm SD$ .

<sup>2-5</sup>Significantly different from non-tea drinkers (ANOVA): <sup>2</sup>P = 0.03, <sup>3</sup>P = 0.02, <sup>4</sup>P < 0.01, <sup>5</sup>P = 0.04.

**TABLE 3**  
Age- and BMI-adjusted mean bone mineral density at selected sites in women aged 65–76 y

	Bone mineral density			
	Lumbar spine	Femoral neck	Greater trochanter	Ward's triangle
	<i>g/cm<sup>2</sup></i>			
Number of cups of tea/d				
0 ( <i>n</i> = 122)	0.886	0.658	0.586	0.452
1–3 ( <i>n</i> = 438)	0.924	0.671	0.614 <sup>1</sup>	0.483
4–6 ( <i>n</i> = 567)	0.915	0.673	0.612 <sup>1</sup>	0.473
>6 ( <i>n</i> = 129)	0.914	0.661	0.614 <sup>1</sup>	0.468
Addition of milk to tea				
No ( <i>n</i> = 161)	0.923	0.670	0.604	0.477
Yes ( <i>n</i> = 973)	0.917	0.670	0.614 <sup>2</sup>	0.476
Coffee drinkers				
Non-tea drinkers ( <i>n</i> = 107)	0.889	0.661	0.586	0.450
Tea drinkers ( <i>n</i> = 918)	0.924 <sup>3</sup>	0.674	0.616 <sup>4</sup>	0.482 <sup>4</sup>
Non-coffee drinkers				
Non-tea drinkers ( <i>n</i> = 15)	0.867	0.631	0.593	0.462
Tea drinkers ( <i>n</i> = 216)	0.900	0.659	0.604	0.459
Excluding current smokers				
Non-tea drinkers ( <i>n</i> = 106)	0.890	0.660	0.587	0.453
Tea drinkers ( <i>n</i> = 1039)	0.921	0.673	0.615 <sup>5</sup>	0.479 <sup>6</sup>
Excluding current users of hormone replacement therapy				
Non-tea drinkers ( <i>n</i> = 94)	0.877	0.658	0.585	0.452
Tea drinkers ( <i>n</i> = 1090)	0.914 <sup>3</sup>	0.667	0.609	0.477 <sup>3</sup>

<sup>1</sup>Significantly different from women who drank no tea, *P* = 0.04.

<sup>2</sup>Significantly different from women who did not add milk to their tea, *P* = 0.01 (ANOVA).

<sup>3–6</sup>Significantly different from non-tea drinkers (ANOVA): <sup>3</sup>*P* = 0.04, <sup>4</sup>*P* = 0.01, <sup>5</sup>*P* = 0.006, <sup>6</sup>*P* = 0.03.

excluded, the associations with tea drinking were still apparent (Table 3). There was no significant interaction between tea drinking and either smoking or hormone replacement therapy.

The multiple regression analysis of BMD at selected sites with tea drinking is shown in **Table 4**. BMD at all femoral sites was significantly and independently inversely related to age and positively related to BMI. BMD at the lumbar spine was strongly related to BMI but not to age. Current use of hormone replacement therapy was also positively related to BMD at all sites. There was no independent significant relation of BMD with current smoking or coffee drinking. BMD at the lumbar spine, greater trochanter, and Ward's triangle was significantly related to tea drinking independent of other variables, including age, BMI, use of hormone replacement therapy, coffee drinking, and smoking status.

## DISCUSSION

Tea drinking was associated with higher BMD in this population of older women. This association was independent of age, BMI, and potential confounding factors, including addition of milk to tea, coffee drinking, smoking status, and use of hormone replacement therapy. This association was not related to the number of cups of tea drunk per day.

This study had several limitations. Estimates of dietary intake are problematic because of measurement error in characterizing subjects as tea drinkers or non-tea drinkers. Additionally, we had information only on current, not past, intakes of tea and coffee. It was thus surprising that an association between self-reported tea drinking and BMD could be found, given the potential measurement error in characterizing individual intakes. Nevertheless,

lack of power from random measurement error would tend to reduce the magnitude of any relation.

Of the women from the general community who were invited to participate in the study, only about half did so. However, selection bias is unlikely to explain the association between tea drinking and BMD that we observed. For this to occur, there would have to have been a differential nonresponse either from women who had both low BMD and a high tea intake or from women who had high BMD and a low tea intake, and there is no reason to suppose that this was the case.

Because the addition of milk to tea is commonplace in Britain, the consumption of milk, an important source of calcium, could have been a confounder in the relation between tea drinking and BMD. However, mean BMD was similar in women who did and women who did not add milk to their tea at all sites except the greater trochanter, where mean BMD was higher in women who added milk to their tea. Although an independent effect of milk consumption on BMD cannot be excluded, the higher BMD of women who drank tea with no milk than in women who did not drink tea is consistent with an effect of tea independent of the addition of milk to tea.

Slightly more non-tea drinkers than tea drinkers were currently using hormone replacement therapy. Although women using hormone replacement therapy had higher BMD measurements at all sites, as would be expected, the relation between BMD and tea drinking was independent of hormone replacement therapy. Smoking status also did not explain the association between tea drinking and BMD; there were in fact fewer smokers among the non-tea drinkers.

Several studies showed an inverse association between estimated caffeine intake and BMD in older women (6–9). Those

**TABLE 4**

Multiple regression analysis of bone mineral density at selected sites with tea drinking and other variables in women aged 65–76 y<sup>1</sup>

	Regression of bone mineral density <i>g/cm<sup>2</sup></i>
<b>Lumbar spine</b>	
Tea drinker (yes versus no)	0.037 ± 0.017 <sup>2</sup>
Age (per year)	−0.001 ± 0.001
BMI (per kg/m <sup>2</sup> )	0.015 ± 0.001 <sup>3</sup>
Smoking (yes versus no)	−0.008 ± 0.016
User of hormone replacement therapy (yes versus no)	0.063 ± 0.023 <sup>4</sup>
Coffee drinker (yes versus no)	0.019 ± 0.012
<b>Femoral neck</b>	
Tea drinker (yes versus no)	0.011 ± 0.010
Age (per year)	−0.004 ± 0.001 <sup>3</sup>
BMI (per kg/m <sup>2</sup> )	0.010 ± 0.001 <sup>3</sup>
Smoking (yes versus no)	−0.001 ± 0.010
User of hormone replacement therapy (yes versus no)	0.037 ± 0.014 <sup>4</sup>
Coffee drinker (yes versus no)	0.008 ± 0.007
<b>Greater trochanter</b>	
Tea drinker (yes versus no)	0.024 ± 0.010 <sup>5</sup>
Age (per year)	−0.003 ± 0.001 <sup>3</sup>
BMI (per kg/m <sup>2</sup> )	0.009 ± 0.001 <sup>3</sup>
Smoking (yes versus no)	−0.003 ± 0.010
User of hormone replacement therapy (yes versus no)	0.053 ± 0.013 <sup>3</sup>
Coffee drinker (yes versus no)	0.005 ± 0.007
<b>Ward's triangle</b>	
Tea drinker (yes versus no)	−0.026 ± 0.012 <sup>6</sup>
Age (per year)	−0.006 ± 0.001 <sup>3</sup>
BMI (per kg/m <sup>2</sup> )	0.009 ± 0.001 <sup>3</sup>
Smoking (yes versus no)	−0.007 ± 0.012
User of hormone replacement therapy (yes versus no)	0.028 ± 0.016
Coffee drinker (yes versus no)	0.014 ± 0.009

<sup>1</sup>B ± SE.

<sup>2</sup>P = 0.02.

<sup>3</sup>P < 0.001.

<sup>4</sup>P < 0.01.

<sup>5</sup>P = 0.01.

<sup>6</sup>P = 0.03.

studies were conducted in populations in which coffee drinking predominated and was the major source of caffeine (≈80%); indeed, the analysis from Barrett-Connor et al (9) was based on coffee drinking. In contrast with reports from other studies, coffee drinking was not significantly related to BMD in this cohort; in fact, mean BMD was higher (although not significantly so) in coffee drinkers than in non-coffee drinkers. The predominant form of coffee drunk by these older British women was instant coffee, which has different nutritional components than does brewed coffee and may have different biological effects. Also, the addition of milk to coffee is much more prevalent in Britain than in other countries and this could have ameliorated any possible adverse effect of coffee drinking, as suggested by Barrett-Connor (9).


The relation between tea drinking and BMD is less clear. Hernandez et al (13) reported a weak inverse association between ultradistal BMD and tea intake in pre- and perimenopausal women in a subset of the Massachusetts Women's Health Study but Hoover et al (14) reported that tea intake was positively associated with BMD in the lumbar spine and femoral neck in postmenopausal women.

Fracture rate is inversely related to BMD (15), and although the Framingham investigators reported a positive association

between caffeine intake and the rate of hip fracture in older men and women, they pointed out that their information on tea consumption was incomplete (16). It is of interest that in the Nurses' Health Study, of the various dietary sources of caffeine, coffee intake was most strongly related to risk of hip fracture; the relation between tea drinking and fracture risk was in fact inverse, although not significant (17). In Europe, tea drinking was reported to protect against hip fractures in both men and women (10, 11).

Different beverages vary widely in their patterns of micronutrients other than caffeine, and coffee and tea were shown to have very different effects on health and physiologic factors. For example, consumption of brewed coffee was associated with increased cholesterol concentrations (18) and increased risk of heart disease (19, 20), whereas consumption of tea was associated with favorable lipid concentrations (21) and reduced risk of heart disease (22). It is possible that selection bias may account for some of the observed differences in epidemiologic studies, ie, that persons who choose to drink tea or abstain from coffee may be different with respect to health status. Although this may be true in the United States, in Britain tea drinking is much more of a cultural norm, particularly in older women, so women with certain health characteristics are less likely to be self-selected on the basis of tea consumption. We eliminated important confounding due to smoking, estrogen use, and intake of calcium from milk in tea but confounding from other factors not measured could not be completely eliminated. Nevertheless, plausible biological mechanisms were shown for the different actions of tea and coffee. The lipid-raising effect of brewed coffee was shown in randomized trials (23) and a lipid-rich component of brewed coffee was identified (24).

Tea is a major source of isoflavonoids (25), which were shown to have several biological actions, including a weak estrogenic effect (26, 27). Compared with American and European women, Japanese women have a diet that is higher in isoflavonoids (28). High dietary isoflavonoid intake, and consequent estrogenic effect, was therefore suggested as an explanation for the infrequent occurrence of hot flashes and other menopausal symptoms in Japanese women (29). Tamoxifen, which is a partial estrogen agonist, has both estrogenic and antiestrogenic effects, depending on prevailing amounts of estrogen; thus, tamoxifen use appears to be beneficial for bone mass postmenopausally but may have adverse effects premenopausally. It may be that any weak estrogenic effects of isoflavonoids in tea do not have noticeable effect on BMD in premenopausal women with high amounts of endogenous estrogen, such as predominated in the group studied by Hernandez et al (13), or in men, in whom androgens predominate, but may be important in maintaining BMD in older women who have low amounts of endogenous estrogen, such as reported by Hoover et al (14).

The magnitude of the effect of drinking tea was notable. Tea drinkers had ≈5% higher mean BMD at various sites than did non-tea drinkers. This effect was equivalent to about half of the difference in BMD observed in women using hormone replacement therapy compared with women who did not use such therapy, or a decrease in age of ≈5 y, and was associated with a decline in fracture risk of ≈10–20%. This finding may thus be of potential clinical and public health importance. The observation that tea drinking appears to be protective against osteoporosis in older women merits further investigation. 

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