Tea drinking and bone mineral density in older women\textsuperscript{1–3}

Verona M Hegarty, Helen M May, and Kay-Tee Khaw

\textbf{ABSTRACT}

\textbf{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.

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

\textbf{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.

\textbf{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 (\textit{p} \textless 0.004) mean BMD measurements, adjusted for age and body mass index, at the lumbar spine (0.033 g/cm\textsuperscript{2}; \textit{p} = 0.03), greater trochanter (0.028 g/cm\textsuperscript{2}; \textit{p} = 0.004), and Ward’s triangle (0.025 g/cm\textsuperscript{2}; \textit{p} = 0.02). Differences at the femoral neck (0.013 g/cm\textsuperscript{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.

\textbf{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. \textit{Am J Clin Nutr} 2000;71:1003–7.

\textbf{KEY WORDS} Tea, bone mineral density, flavonoids, hormone replacement therapy, osteoporosis, women, United Kingdom

\textbf{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 (\textsuperscript{1, 2}), osteoporosis, or low bone mineral density (BMD), is the single most important known risk factor for fractures in older women (\textsuperscript{1}).

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

\textbf{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 kg/m\textsuperscript{2}) was calculated. The protocol was approved by the Cambridge Health Authority.

\textbf{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 \textgreater 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.
Smoking status

Tea drinkers compared with non–tea drinkers

Bone mineral density measurements

Other variables

Statistical analysis

RESULTS

Tea drinkers compared with non–tea drinkers

Table 1

Table 2

Addition of milk to tea

Coffee drinking

Smoking and hormone replacement therapy

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).

Women who added milk to their tea had significantly higher mean BMD measured at the greater trochanter than those who did not add milk to their tea or non–tea drinkers.

Tea drinkers and hormone replacement therapy, although the differences were 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.

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

Crude bone mineral density at selected sites in 1256 women aged 65–76 y according to self-reported tea drinking

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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

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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 3

<table>
<thead>
<tr>
<th>Age- and BMI-adjusted mean bone mineral density at selected sites in women aged 65–76 y</th>
<th>Bone mineral density</th>
<th>Lumbar spine</th>
<th>Femoral neck</th>
<th>Greater trochanter</th>
<th>Ward’s triangle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/cm²</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of cups of tea/d</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 (n = 122)</td>
<td>0.886</td>
<td>0.658</td>
<td>0.586</td>
<td>0.452</td>
<td></td>
</tr>
<tr>
<td>1–3 (n = 438)</td>
<td>0.924</td>
<td>0.671</td>
<td>0.614</td>
<td>0.483</td>
<td></td>
</tr>
<tr>
<td>4–6 (n = 567)</td>
<td>0.915</td>
<td>0.673</td>
<td>0.612</td>
<td>0.473</td>
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</tr>
<tr>
<td>&gt; 6 (n = 129)</td>
<td>0.914</td>
<td>0.661</td>
<td>0.614</td>
<td>0.468</td>
<td></td>
</tr>
<tr>
<td>Addition of milk to tea</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No (n = 161)</td>
<td>0.923</td>
<td>0.670</td>
<td>0.604</td>
<td>0.477</td>
<td></td>
</tr>
<tr>
<td>Yes (n = 973)</td>
<td>0.917</td>
<td>0.670</td>
<td>0.614</td>
<td>0.476</td>
<td></td>
</tr>
<tr>
<td>Coffee drinkers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non–tea drinkers (n = 107)</td>
<td>0.889</td>
<td>0.661</td>
<td>0.586</td>
<td>0.450</td>
<td></td>
</tr>
<tr>
<td>Tea drinkers (n = 918)</td>
<td>0.924</td>
<td>0.674</td>
<td>0.616</td>
<td>0.482</td>
<td></td>
</tr>
<tr>
<td>Non–coffee drinkers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non–tea drinkers (n = 15)</td>
<td>0.867</td>
<td>0.631</td>
<td>0.593</td>
<td>0.462</td>
<td></td>
</tr>
<tr>
<td>Tea drinkers (n = 216)</td>
<td>0.900</td>
<td>0.659</td>
<td>0.604</td>
<td>0.459</td>
<td></td>
</tr>
<tr>
<td>Excluding current smokers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non–tea drinkers (n = 106)</td>
<td>0.890</td>
<td>0.660</td>
<td>0.587</td>
<td>0.453</td>
<td></td>
</tr>
<tr>
<td>Tea drinkers (n = 1039)</td>
<td>0.921</td>
<td>0.673</td>
<td>0.615</td>
<td>0.479</td>
<td></td>
</tr>
<tr>
<td>Excluding current users of hormone replacement therapy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non–tea drinkers (n = 94)</td>
<td>0.877</td>
<td>0.658</td>
<td>0.585</td>
<td>0.452</td>
<td></td>
</tr>
<tr>
<td>Tea drinkers (n = 1090)</td>
<td>0.914</td>
<td>0.667</td>
<td>0.609</td>
<td>0.477</td>
<td></td>
</tr>
</tbody>
</table>

1 Significantly different from women who drank no tea, P = 0.04.
2 Significantly different from women who did not add milk to their tea, P = 0.01 (ANOVA).
3 Significantly different from non-tea drinkers (ANOVA): 1 P = 0.04, 4 P = 0.01, 5 P = 0.006, 6 P = 0.03.
the Framingham investigators reported a positive association in the lumbar spine and femoral neck in postmenopausal women. Hoover et al (14) reported that tea intake was positively associated with BMD in a subset of the Massachusetts Women’s Health Study but no difference in BMD observed in women using hormone replacement therapy in older women merits further investigation.

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.
REFERENCES