



Habitual Tea Consumption and Risk of Osteoporosis: A Prospective Study in the Women's Health Initiative Observational Cohort

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Received for publication February 25, 2003; accepted for publication April 22, 2003.

The purpose of this study was to prospectively investigate associations of habitual drinking of regular tea with bone mineral density and fracture risk. Study participants were a multiethnic postmenopausal cohort ($n = 91,465$) from the nationwide Women's Health Initiative Observational Study. These women were recruited in the United States and aged 50–79 years at the time of enrollment (1994–1998). The average follow-up time was 4.1 years. Habitual consumption of regular tea was assessed with a structured questionnaire at baseline. Clinical fractures during the follow-up were reported in questionnaires, and hip fractures were further confirmed by reviewing medical records. Bone mineral density measurements were conducted among a subgroup of women ($n = 4,979$) at three Women's Health Initiative bone mineral density centers using dual-energy x-ray absorptiometry. Multivariate analyses suggested a positive trend of increased total body bone mineral density with tea drinking ($p < 0.05$). However, results from the Cox proportional hazard models did not show any significant association between tea drinking and the risk of fractures at the hip and forearm/wrist. In conclusion, the results from this study indicate that the effect of habitual tea drinking on bone density is small and does not significantly alter the risk of fractures among the US postmenopausal population.

bone density; cohort studies; densitometry; fractures; osteoporosis, postmenopausal; tea; women

Abbreviations: MEDOS, Mediterranean Osteoporosis; WHI, Women's Health Initiative.

Tea is widely consumed throughout the world. The health benefits of this ancient beverage in preventing cancers, rheumatoid arthritis, and cardiovascular diseases are under intensive investigation (1–3). Recently, a possible relation between tea drinking and osteoporosis has also been suggested (4–9). However, previous studies on bone mineral density and tea consumption are all cross-sectional, and the results are inconsistent. An inverse relation between tea consumption and bone mineral density was found in a study among pre- and perimenopausal women (50–60 years of age) in the United States (4). In contrast, a positive relation between tea drinking and bone mineral density was reported among postmenopausal women in Canada (5) and in the

United Kingdom (6) and more recently among Asian older men and women (8).

The effect of tea drinking on fracture risk has been studied only in one cross-sectional sample. Results from the Mediterranean Osteoporosis (MEDOS) Study showed that tea drinking was associated with 30 percent reduction in the risk of hip fractures in both women (7) and men (9) over 50 years of age. This finding is intriguing but needs replication in longitudinal studies and among other populations, such as the populations in the United States, where the level and type of tea consumption may differ from those in European countries.

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Tea is an important source of phytoestrogen and fluoride, both of which may help to maintain bone mineral density. However, regular tea (not decaffeinated or herbal tea) also contains caffeine that, in a high amount, may cause bone loss. The impact of drinking regular tea on the risk of osteoporosis has not been studied before. Results from a previous study conducted in Arizona indicated that over 90 percent of tea drinkers consumed regular tea instead of decaffeinated tea (10). The purpose of this study was to prospectively investigate if daily consumption of regular tea is related to bone density and fracture risk among a large postmenopausal cohort from the Women's Health Initiative (WHI) Observational Study in the United States.

MATERIALS AND METHODS

Study population

The study population was a cohort from the nationwide WHI Observational Study. Postmenopausal women aged 50–79 years were enrolled in the WHI Observational Study at 40 clinical centers throughout the United States. Details of the study methods were reported elsewhere (11). In summary, women were recruited from communities where the WHI clinical centers are located. Eligibility for the WHI Observational Study included postmenopausal status, stability (being unlikely to move or die within 3 years), nonenrollment in the WHI clinical trials, and nonparticipation in any other current clinical trials. This WHI Observational Study cohort comprised non-Hispanic White, Hispanic, Black, American Indian, and Asian/Pacific Islander women. As of August 31, 2001, a total of 93,676 participants were enrolled in the WHI Observational Study. Less than 1 percent ($n = 811$) had no follow-up information, and 1.5 percent ($n = 1,442$) were missing information on tea consumption. Excluding these participants left 91,465 women eligible for this study.

Study procedure

At baseline, women completed self-administered or interviewer-administered questionnaires for eligibility screening and baseline characteristics (such as demographic, reproductive, and health status data). Physical examinations were conducted, and a blood specimen was collected. During the follow-up, women were sent questionnaires annually to update medical and other lifestyle information. The WHI Observational Study women visited the WHI clinical center at annual visit 3 to have additional physical measurements taken and to provide a blood specimen. Additional follow-up data collections were done through annual mailed questionnaires. The average length of follow-up was 4.1 years as of August 31, 2001. The WHI study protocol was reviewed and approved by human subjects review committees at each participating institution.

Tea consumption

All women in this study completed a WHI Observational Study questionnaire at baseline, in which separate questions

about tea and coffee drinking were asked. The tea question was phrased in the following way: "Do you usually drink tea each day (do not include decaffeinated or herbal tea)?" The daily tea drinkers were further classified as drinking 1 cup/day, 2–3 cups/day, 4–5 cups/day, and 6 or more cups/day (1 cup = 0.237 liter).

Fracture assessments

Women reported the occurrence of any clinical fractures by completing WHI follow-up questionnaires each year. Self-reports of hip fractures were confirmed by review of medical records. Only confirmed hip fractures were used in this study. Other non-hip fracture data were all based upon self-report. Spinal fractures were self-reported clinical fractures of the thoracic or lumbar spine. Lower arm and wrist fractures were self-reported fractures of the radius, ulna, or carpal. Other self-reported fractures in this study included fractures of the upper leg (shaft of femur), pelvis, knee (patella or tibial plateau), lower leg or ankle (tibia, fibula, or talus), foot (tarsal, metatarsal, heel, or calcaneus), tailbone (sacrum or coccyx), hand (metacarpal), elbow (distal humerus, upper radius, or ulna), and upper arm, shoulder, or collarbone (humerus, clavicle, or scapula).

Moderate-to-excellent agreements between self-reports of fractures and medical records were found for different skeletal sites, and these results will be reported in a separate paper.

Bone density measurements in a subsample

Bone mineral density of the posterior-anterior spine, total hip, and total body was measured as area density (g/cm^2) at three WHI bone mineral density clinic centers (Pittsburgh, Pennsylvania, Birmingham, Alabama, and Tucson/Phoenix, Arizona) using dual-energy x-ray absorptiometry (QDR bone densitometer; Hologic, Inc., Waltham, Massachusetts). The positioning and analysis of these x-ray absorptiometry scans were performed according to standard WHI protocols by radiology technicians who were trained and certified by both the Hologic company and the WHI Bone Density Coordinating Center at the University of California, San Francisco. The ongoing WHI quality assurance program monitors machine and technicians' performance by reviewing phantom scans, a random sample of all scans, and scans with specific problems and by controlling hardware and software changes. In addition to daily and weekly phantom scans at each clinic, a set of calibration phantoms were also periodically circulated and scanned across dual-energy x-ray absorptiometry instruments in the WHI.

The rate of study participants either withdrawn or lost to follow-up was 1.7 percent for the bone mineral density cohort. A total of 5,063 participants had bone mineral density measurements at both the baseline visit and the annual visit 3 follow-up visit, but 1.7 percent of these women did not have tea consumption data. Excluding women with incomplete bone mineral density or tea consumption information, we found that there were 4,979 participants in the bone mineral density cohort for analyses related to bone mineral density and tea consumption. Because two of the three WHI bone mineral density centers

TABLE 1. Baseline characteristics of the total study population by tea consumption, Women's Health Initiative Observational Study, 1994–2001

	Cups of tea/day*				Total (%) (n = 91,465)
	<1 cup/day (%) (n = 68,188)	1 cup/day (%) (n = 11,363)	2–3 cups/day (%) (n = 9,480)	≥4 cups/day (%) (n = 2,434)	
Age group at screening (years)					
50–59	32.27	29.14	29.79	34.51	31.68
60–69	44.04	44.33	43.67	43.80	44.03
70–79	23.69	26.53	26.54	21.69	24.29
Years since menopause					
<5	13.09	12.12	12.48	13.02	12.91
5–<10	17.77	17.85	16.62	18.36	17.68
10–<15	19.60	18.67	19.10	20.13	19.45
≥15	49.53	51.37	51.79	48.49	49.97
Ethnicity					
White	82.94	85.05	85.82	89.36	83.67
Black	8.88	6.04	4.92	2.92	7.96
Hispanic	3.91	3.26	2.84	2.22	3.67
American Indian	0.46	0.29	0.47	0.45	0.44
Asian/Pacific Islander	2.46	3.98	4.30	3.82	2.88
Other/unspecified	1.35	1.39	1.65	1.23	1.38
Body mass index (kg/m ²)					
<18.5	1.18	1.40	1.11	1.33	1.20
18.5–24.9	39.35	41.86	39.95	39.95	39.74
25.0–29.9	33.86	34.15	34.76	34.14	34.00
30.0–39.9	21.97	19.76	20.79	20.68	21.54
≥40.0	3.63	2.83	3.39	3.90	3.52
Smoking					
Never smoked	49.71	55.08	54.69	50.10	50.91
Former smoker	43.75	40.32	40.12	40.27	42.86
Current smoker	6.53	4.61	5.19	9.62	6.24
Soy milk (servings/day)					
0	98.64	98.53	98.51	98.68	98.61
>0–≤1	0.64	0.71	0.65	0.72	0.66
>1	0.71	0.76	0.84	0.60	0.73
Calcium supplements (mg/day)					
0	40.25	38.41	40.88	41.41	40.12
>0–600	34.55	36.15	34.96	34.06	34.78
>600–1,200	18.26	18.58	17.41	18.61	18.22
>1,200	6.94	6.86	6.67	5.92	6.88

Table continues

were designated minority clinical sites, there was a slightly higher percentage of minorities enrolled in the bone mineral density cohort than in the entire WHI Observational Study.

Assessments of covariates

Information on age, years since menopause, race/ethnicity, smoking, soy milk consumption, regular coffee consumption, time spent on walking, hormone replacement therapy, use of medications for osteoporosis, fracture history, and

nutrient intakes was assessed from baseline questionnaires. Physical function and depression at baseline were measured using the 10-item Medical Outcomes Study Scale (12) and the shortened Center for Epidemiologic Studies Depression Scale, respectively (13). Weight was measured to the nearest 0.1 kg on a balance beam scale with the participant dressed in indoor clothing without shoes. Height was measured to the nearest 0.1 cm using a wall-mounted stadiometer. Body mass index was calculated as the weight (kg)/height (m)² for both the baseline visit and annual visit 3.

TABLE 1. Continued

	Cups of tea/day				Total (%) (n = 91,465)
	<1 cup/day (%) (n = 68,188)	1 cup/day (%) (n = 11,363)	2–3 cups/day (%) (n = 9,480)	≥4 cups/day (%) (n = 2,434)	
Cups of regular coffee/day					
0	42.29	38.73	52.10	69.22	43.59
1	16.87	22.99	16.70	11.32	17.46
2–3	30.02	31.96	25.01	14.35	29.32
≥4	10.82	6.32	6.19	5.10	9.63
Minutes/week spent walking					
0	41.68	38.65	42.08	43.92	41.40
>0–150	42.04	44.43	42.10	40.18	42.29
>150	16.29	16.91	15.82	15.90	16.31
Physical function construct					
≤90	61.77	61.40	63.19	63.53	61.92
>90	38.23	38.60	36.81	36.47	38.08
Depression (shortened CES-D† Scale)					
No	88.73	89.22	88.80	86.73	88.74
Yes (≥0.06)	11.27	10.78	11.20	13.27	11.26
Broke bone at age 55 years or later					
No	85.36	84.88	84.44	85.27	85.20
Yes	14.64	15.13	15.56	14.73	14.80
Years used HRT† (currently)					
Never/past user	55.15	56.65	56.61	57.34	55.54
<5	0.53	0.49	0.54	0.66	0.53
5–<10	1.29	1.14	0.95	1.36	1.24
10–<15	1.49	1.44	1.14	1.15	1.44
≥15	41.54	40.27	40.77	39.50	41.25
Osteoporosis medication					
No	96.00	95.44	96.19	96.63	95.97
Yes	4.00	4.56	3.81	3.37	4.03
	Mean (SD)†	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Age (years)	63.5 (7.4)	64.2 (7.3)	64.1 (7.4)	63.1 (7.3)	63.6 (7.4)
Dietary calcium/total energy intake (mg/kcal)	0.46 (0.19)	0.46 (0.17)	0.45 (0.17)	0.45 (0.17)	0.46 (0.18)

* One cup = 0.237 liter.

† CES-D, Center for Epidemiologic Studies Depression; HRT, hormone replacement therapy; SD, standard deviation.

Statistical analysis

There were only 31 women in the bone mineral density cohort and 543 women in the entire cohort who drank 6 or more cups of tea per day (1 cup = 0.237 liter). Results from the preliminary analysis indicated that the directions and magnitudes of the associations between tea and bone mineral density or fracture risk were similar between the groups drinking 6 or more cups per day and 4–5 cups per day. Hence, women in the group drinking 6 or more cups per day were combined with the group drinking 4–5 cups per day for adequate statistical power in the analyses. Characteristics of the participants at baseline were described by four tea consumption groups: group I (<1 cup/day), group II (1 cup/day), group III (2–3 cups/day), and group IV (≥4 cups/day). Crude and adjusted least-squares mean bone mineral density

measurements were reported for each tea-drinking group. Multivariate linear regression analysis and the trend test were used to assess the associations of baseline tea drinking with bone mineral density measurements at annual visit 3 (or the changes in bone mineral density by percentage from baseline to annual visit 3). The major covariates include ethnicity (White as reference vs. Black, Hispanic, American Indian, Asian/Pacific Islander, other/unspecified), age (years), body mass index (kg/m²), the ratio of dietary calcium to total energy (mg/kcal) assessed using the WHI food questionnaire (log transformed), calcium supplements (none vs. >0–600 mg, >600–1,200 mg, or >1,200 mg/day), hormone replacement therapy use (never vs. past or current), coffee drinking (nondrinker vs. drinker), walking (none vs. 0–150 minutes/week or >150 minutes/week), and smoking (never vs. former or current). Multivariate analyses were

TABLE 2. Baseline characteristics of the bone mineral density study participants by tea consumption, Women's Health Initiative Observational Study, 1994–2001

	Cups of tea per day*				Total (%) (n = 4,979)
	<1 cup/day (%) (n = 3,683)	1 cup/day (%) (n = 566)	2–3 cups/day (%) (n = 588)	≥4 cups/day (%) (n = 142)	
Age group at screening (years)					
50–59	32.23	28.62	29.42	44.37	31.83
60–69	43.71	48.94	45.75	40.85	44.47
70–79	24.06	22.44	24.83	14.79	23.70
Years since menopause					
<5	11.90	10.41	10.91	13.39	11.65
5–<10	16.56	17.10	17.27	18.11	16.75
10–<15	19.74	20.26	20.73	21.26	19.96
≥15	51.81	52.23	51.09	47.24	51.65
Ethnicity					
White	77.87	84.28	87.76	88.03	80.06
Black	13.25	8.30	4.76	5.63	11.47
Hispanic	6.57	4.24	4.42	4.93	6.01
American Indian	1.33	1.24	1.70	0.70	1.35
Asian/Pacific Islander	0.27	1.41	0.51	0.70	0.44
Other/unspecified	0.71	0.53	0.85	0.00	0.68
Body mass index (kg/m ²)					
<18.5	1.32	1.60	1.02	1.41	1.32
18.5–24.9	38.46	42.07	37.71	30.28	38.55
25.0–29.9	33.77	35.29	34.30	33.10	33.99
30.0–39.9	22.29	18.18	21.50	28.17	21.90
≥40.0	4.17	2.85	5.46	7.04	4.25
Smoking					
Never smoked	53.03	61.87	60.07	46.81	54.69
Former smoker	39.48	32.01	35.67	36.88	38.10
Current smoker	7.49	6.12	4.27	16.31	7.21
Soy milk (servings/day)					
0	99.17	99.45	99.13	99.28	99.20
>0–≤1	0.43	0.18	0.52	0.72	0.42
>1	0.40	0.37	0.35	0.00	0.38
Calcium supplements (mg/day)					
0	48.41	48.23	51.02	54.93	48.89
>0–600	28.62	28.80	28.74	28.87	28.66
>600–1,200	16.29	16.25	13.27	13.38	15.85
>1,200	6.68	6.71	6.97	2.82	6.61

Table continues

also conducted in stratified samples by ethnicity and hormone replacement therapy to assess the strength of the associations between tea and bone mineral density in each subgroup. Interaction terms between ethnicity (or hormone replacement therapy) and tea consumption were computed and tested for levels of significance.

Cox proportional hazards survival models were used to calculate crude and adjusted relative risks and corresponding 95 percent confidence intervals for each fracture type, including fractures at the hip (femoral neck, intertrochanteric region, and greater trochanter), at the forearm/wrist (radius, ulna, or carpal), and at other skeletal sites, by tea-drinking

group. The variables included in the adjusted Cox models were age, body mass index, hormone replacement therapy use, smoking, years since menopause, fracture history (broken bone at age 55 years or later, yes vs. no), osteoporosis drug use (yes vs. no), walking, soy milk consumption, coffee drinking, and depression (yes vs. no). To examine if the association of fracture with tea consumption varied by ethnicity or hormone replacement therapy use, the relative risks and 95 percent confidence intervals within these subgroups were computed. The statistical analyses were performed using SAS (version 8.2) statistical software (SAS Institute, Inc., Cary, North Carolina). In all multivariate

TABLE 2. Continued

	Cups of tea per day				Total (%) (n = 4,979)
	<1 cup/day (%) (n = 3,683)	1 cup/day (%) (n = 566)	2–3 cups/day (%) (n = 588)	≥4 cups/day (%) (n = 142)	
Dietary calcium/total energy intake (mg/kcal)	0.46	0.45	0.44	0.42	0.46
Cups of regular coffee/day					
0	44.51	36.48	49.40	63.38	44.72
1	15.29	24.73	15.56	9.15	16.23
2–3	28.92	32.21	27.86	19.72	28.90
≥4	11.28	6.58	7.18	7.75	10.15
Minutes/week spent walking					
0	45.51	38.69	50.17	47.89	45.35
>0–150	39.53	45.41	36.56	35.21	39.73
>150	14.96	15.90	13.27	16.90	14.92
Physical function construct					
≤90	66.48	64.49	66.78	69.72	66.39
>90	33.52	35.51	33.22	30.28	33.61
Depression (shortened CES-D† Scale)					
No	87.34	86.15	85.86	81.56	86.86
Yes (≥0.06)	12.66	13.85	14.14	18.44	13.14
Broke bone at age 55 years or later					
No	84.48	83.27	85.60	91.20	84.67
Yes	15.52	16.73	14.40	8.80	15.33
Years used HRT† (currently)					
Never/past user	58.30	58.83	58.16	61.97	58.45
<5	0.71	0.18	0.51	0.00	0.60
5–<10	1.25	1.06	1.02	0.00	1.17
10–<15	1.85	1.77	1.19	0.00	1.71
≥15	37.90	38.16	39.12	38.03	38.08
Osteoporosis medication					
No	97.07	97.35	97.28	97.89	97.15
Yes	2.93	2.65	2.72	2.11	2.85
	Mean (SD)†	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Age (years)	63.5 (7.4)	63.8 (6.9)	63.8 (7.6)	61.7 (7.6)	63.5 (7.4)
Dietary calcium/total energy intake (mg/kcal)	0.46 (0.18)	0.45 (0.16)	0.44 (0.17)	0.42 (0.16)	0.46 (0.17)
Bone mineral density (g/cm ²)					
Total body	1.012 (0.105)	1.006 (0.106)	1.009 (0.105)	1.020 (0.114)	
Lumbar spine (L2–L4)	0.975 (0.170)	0.960 (0.169)	0.973 (0.161)	1.000 (0.163)	
Total hip	0.843 (0.137)	0.833 (0.139)	0.838 (0.134)	0.857 (0.139)	

* One cup = 0.237 liter.

† CES-D, Center for Epidemiologic Studies Depression; HRT, hormone replacement therapy; SD, standard deviation.

models, a complete-case approach was used for the handling of missing data. Adjusted variables were selected for the multivariate models based on results from previous studies and their effects on the study results in preliminary data analyses.

RESULTS

Baseline characteristics

Among 91,465 participants, 68,188 (75 percent) women did not drink tea daily, 11,363 (12 percent) drank 1 cup per

day, 9,480 (10 percent) drank 2–3 cups per day, and 2,434 (3 percent) drank 4 or more cups of tea per day (1 cup = 0.237 liter). Most of the characteristics at baseline were comparable among tea consumption groups. However, Black women were less likely to drink tea in comparison with women from other ethnic groups. There was an apparent inverse correlation between tea drinking and coffee consumption (table 1).

Baseline characteristics of the bone mineral density cohort are presented in table 2. The sample sizes were 3,683, 566, 588, and 142, respectively, for the four tea groups from low

TABLE 3. Crude and adjusted* bone mineral density at annual visit 3 by tea consumption (n = 4,979), Women's Health Initiative Observational Study, 1994–2001

Bone mineral density (g/cm ²)	<1 cup/day† (n = 3,683)		1 cup/day (n = 566)		2–3 cups/day (n = 588)		≥4 cups/day (n = 142)		Trend test p value
	Mean	95% confidence interval	Mean	95% confidence interval	Mean	95% confidence interval	Mean	95% confidence interval	
Total body									
Crude	1.022	1.019, 1.026	1.013	1.003, 1.022	1.021	1.012, 1.030	1.035	1.016, 1.053	0.90
Adjusted	1.021	1.020, 1.022	1.019	1.016, 1.022	1.024	1.021, 1.027	1.029‡	1.023, 1.036	0.03
Total hip									
Crude	0.847	0.843, 0.852	0.838	0.826, 0.849	0.843	0.832, 0.855	0.859	0.836, 0.882	0.87
Adjusted	0.846	0.845, 0.847	0.847	0.844, 0.850	0.848	0.845, 0.851	0.846	0.840, 0.850	0.22
Lumbar spine									
Crude	0.990	0.984, 0.996	0.977	0.962, 0.991	0.993	0.979, 1.007	1.015	0.986, 1.045	0.39
Adjusted	0.989	0.988, 0.991	0.991	0.986, 0.995	0.995‡	0.991, 0.999	0.990	0.981, 0.998	0.06

* Adjusted for baseline bone mineral density, age, body mass index, ethnicity, hormone replacement therapy use, dietary calcium/total energy, calcium supplements, coffee, walking, smoking, and body mass index at annual visit 3.

† One cup = 0.237 liter.

‡ Significantly different from the reference group (<1 cup/day), $p < 0.05$.

to high tea consumption. The percentages of minority women in the bone mineral density cohort were higher in comparison with the total study population.

Bone mineral density and tea drinking

Table 3 displays the mean and 95 percent confidence intervals of the annual visit 3 bone mineral density measurements by tea consumption. After adjustment for the major covariates (ethnicity, baseline measurements on bone mineral density, age, body mass index, hormone replacement therapy use, dietary calcium/total energy, calcium supplements, coffee, walking, smoking, and annual visit 3 body mass index), drinking 4 or more cups of tea per day was associated with higher total body bone mineral density at annual visit 3 ($p < 0.05$), while consuming 2–3 cups of tea per day was associated with higher spinal bone mineral density at annual visit 3 ($p < 0.05$) in comparison with nondaily tea drinkers. There was a significant trend of increased total body bone mineral density with a higher level of tea consumption. However, significant trends were not found for either total hip or lumbar spine bone mineral density. Models with the rates of change in bone mineral density measurements between baseline and annual visit 3 provided results similar to those of the models using annual visit 3 bone mineral density measurements as outcomes (data not shown). There were no significant interactions between ethnicity (or hormone replacement therapy) and tea consumption on bone mineral density (data not shown).

Fractures and tea drinking

There were 386 hip fractures, 1,809 forearm/wrist fractures, and 8,332 other fractures during 363,811 person-years of follow-up. The other major fractures were fractures of the

lower leg or ankle (tibia, fibula, or talus), foot (tarsal, metatarsal, heel, or calcaneus), and upper arm, shoulder, or collarbone (humerus, clavicle, or scapula). In general, the crude and adjusted relative risk and 95 percent confidence interval for each type of fracture did not suggest a significant relation between tea consumption and fracture risk of the hip and forearm/wrist. Women who consumed 2–3 cups of tea per day appeared to have an increased relative risk for fractures other than the hip and forearm/wrist in comparison with women who did not drink tea daily (table 4). However, this association between other fracture risk and tea drinking was no longer significant when the analyses were restricted to the non-Hispanic White women only (data not shown). Because of the small number of fractures in minority women, we were unable to examine the effect of tea drinking on fracture risk in these subgroups.

DISCUSSION

Unlike the previous cross-sectional study conducted among US pre- and perimenopausal women (4), results from our US postmenopausal cohort do not support an inverse relation between tea drinking and bone mineral density. Instead, we found a positive trend between daily consumption of regular tea and total body bone mineral density. This result is consistent with findings from other researchers among postmenopausal women in Canada (5), older women (65–76 years) in the United Kingdom (6), and adult women and men in Asia (8), which have shown an increased axial bone mineral density (hip and spine) and/or increased total body bone mineral density among tea drinkers. The differences in menopausal status and skeletal sites measured may contribute to the discrepancies in research findings.

Tea may affect bone mineral density through several distinct mechanisms. First, tea is a rich source of caffeine. It

TABLE 4. Crude and adjusted* relative risk of fractures by tea consumption, Women's Health Initiative Observational Study, 1994–2001

	Total no.	Hip fractures			Forearm/wrist fractures			Other fractures		
		No. of fractures	Relative risk	95% confidence interval	No. of fractures	Relative risk	95% confidence interval	No. of fractures	Relative risk	95% confidence interval
<1 cup/day†	68,188	280			1,339			4,881		
Crude			1.00			1.00			1.00	
Adjusted			1.00			1.00			1.00	
1 cup/day	11,363	51			237			794		
Crude			1.10	0.81, 1.48		1.07	0.93, 1.23		0.98	0.91, 1.06
Adjusted			1.05	0.74, 1.48		1.06	0.90, 1.24		0.98	0.90, 1.07
2–3 cups/day	9,480	45			191			757		
Crude			1.15	0.84, 1.58		1.02	0.88, 1.18		1.11	1.03, 1.20
Adjusted			0.98	0.67, 1.44		0.97	0.82, 1.16		1.10	1.01, 1.20
≥4 cups/day	2,434	10			42			194		
Crude			0.99	0.53, 1.86		0.85	0.63, 1.16		1.09	0.95, 1.26
Adjusted			0.93	0.44, 1.98		0.93	0.66, 1.30		1.04	0.88, 1.22

* Adjusted for age, body mass index, ethnicity, hormone replacement therapy use, smoking, years since menopause, fracture history, osteoporosis drug use, walking, soy milk consumption, coffee drinking, and depression.

† Reference group (<1 cup (0.237 liter)/day).

has been suggested that caffeine intake is inversely related to bone mineral density by some studies (4, 14) but not by all studies (15, 16). This discrepancy may be due partially to the addition of milk to coffee that could ameliorate the adverse effects of coffee drinking (6, 14). Although the caffeine content of the tealeaf is higher (2–3 percent vs. 1 percent) compared with that of roasted coffee, tea is diluted more than coffee for drinking. The average caffeine content of a tea beverage in the United States is about 30–45 mg/cup, while that of a coffee beverage is about 60–129 mg/cup (17). Hence, an adverse effect of caffeine from tea on bone mineral density may be less significant. In our study after adjustment for coffee intake, drinking even up to 4 or more cups of regular tea per day did not show any adverse impact on bone mineral density. Tea is an important dietary source of flavonoids (18), and some of them have weak estrogenic effects (19) and well-known antioxidation properties (20), which may be beneficial for bone mineral density. One recent study has also suggested that the catechins derived from green tea are potent stimulators of osteoblast-like cells in culture and that the effects on osteoblast-like cells are, at least in part, via estrogen receptors (21). Furthermore, tea is a major dietary source of fluoride. Fluoride is a very potent and highly bone-specific anabolic substance (22). However, the role of fluoride in fracture prevention is still in debate.

We did not find any significant association between tea consumption and the risk of fractures at the two major osteoporotic fracture sites, the hip and forearm/wrist. Our results differ from the findings of the MEDOS Study (7, 9), in which a significant association between tea consumption and a reduced risk of hip fracture was observed in both women (7) and men (9). The MEDOS Study was a case-control study among people aged 50 years or over from 14

centers in six countries in southern Europe between 1988 and 1989, while our study was conducted in a healthy and multiethnic cohort in the United States. The MEDOS Study and WHI populations may consume different types of tea and possess different risk factors for hip fractures that likely contribute to the different results from the two studies.

We observed a small but significant increase in the risk of fractures at skeletal sites other than the hip and forearm/wrist in the group of women who consumed 2–3 cups of regular tea per day. The other fracture category in this study is a mixed group of fractures, some of which may be mainly caused by extrinsic factors, such as trauma. Given the facts that the daily consumption of regular tea was associated with neither low bone mineral density nor increased risk of fracture at the major osteoporotic sites and that this increased risk of other fractures disappeared in the analyses stratified by ethnic groups, the observed high risk for other fractures in the group drinking 2–3 cups of tea per day is likely caused by unidentified confounding factors.

This is the first cohort study investigating the effect of tea on the risk of osteoporosis. The strengths of our study include a prospective study design, large multiethnic populations, available information on a large range of covariates, and good assessments of both bone mineral density and clinical fractures. However, participants in the WHI cohort may be a selected group of women who are willing to be followed for up to 9 years in the WHI Observational Study. How the selection bias may affect the study results is difficult to assess, but it should be taken into consideration when generalizing the results to other US populations. It is possible that some of the women in our study drank tea sporadically or drank decaffeinated tea instead. Having no information for decaffeinated tea consumption and nondaily tea drinking in

the reference group is a weakness of this study and may mask an association between tea consumption and bone mineral density or fractures. According to a study conducted in Arizona, 33 percent of people may be occasional tea drinkers (drink 1 cup of tea 1–5 times per week), and about 10 percent of the population may drink decaffeinated tea (10). Because of the potential adverse effect of caffeine on bone density, we believe that not counting decaffeinated tea consumption in our study may lead to an underestimate of the strength of any positive association between bone density and tea consumption. Black tea is the most common type of tea consumed by the American population. Whether black and green teas have different effects on bone health needs further investigation.

In summary, our study suggests that, at the current level of tea consumption in the United States, the effect of drinking regular tea on bone mineral density is weak and unlikely to have any significant impact on fracture risk among the US postmenopausal women. Future studies should include detailed assessments of tea consumption to delineate whether various tea preparations and types of tea, such as green versus black, have different contributions to bone mineral density measurements and the risk of fractures.

ACKNOWLEDGMENTS

The research upon which this publication is based was performed pursuant to the National Institutes of Health contracts for the Women's Health Initiative Clinical Centers and Clinical Coordinating Center. Z. C. is supported by a career development award (1 K01 AR02060) from the Department of Health and Human Services, National Institutes of Health.

The following short list of WHI investigators is acknowledged. *Program Office:* National Heart, Lung, and Blood Institute, Bethesda, Maryland: Jacques E. Rossouw, Linda Pottern, Shari Ludlam, Joan McGowan, and Nancy Morris. *Clinical Coordinating Center:* Fred Hutchinson Cancer Research Center, Seattle, Washington: Ross Prentice, Garnet Anderson, Andrea LaCroix, Ruth E. Patterson, and Anne McTiernan; Bowman Gray School of Medicine, Winston-Salem, North Carolina: Sally Shumaker and Pentti Rautaharju; Medical Research Laboratories, Highland Heights, Kentucky: Evan Stein; University of California at San Francisco, San Francisco, California: Steven Cummings; University of Minnesota, Minneapolis, Minnesota: John Himes; and University of Washington, Seattle, Washington: Bruce Psaty. *Clinical Centers:* Albert Einstein College of Medicine, Bronx, New York: Sylvia Wassertheil-Smoller; Baylor College of Medicine, Houston, Texas: Jennifer Hays; Brigham and Women's Hospital, Harvard Medical School, Boston, Massachusetts: JoAnn Manson; Brown University, Providence, Rhode Island: Annlouise R. Assaf; Emory University, Atlanta, Georgia: Lawrence Phillips; Fred Hutchinson Cancer Research Center, Seattle, Washington: Shirley Beresford; George Washington University Medical Center, Washington, DC: Judith Hsia; Harbor-UCLA Research and Education Institute, Torrance, Cali-

fornia: Rowan Chlebowski; Kaiser Permanente Center for Health Research, Portland, Oregon: Cheryl Ritenbaugh; Kaiser Permanente Division of Research, Oakland, California: Bette Caan; Medical College of Wisconsin, Milwaukee, Wisconsin: Jane Morley Kotchen; MedStar Research Institute/Howard University, Washington, DC: Barbara V. Howard; Northwestern University, Chicago/Evanston, Illinois: Linda Van Horn; Rush-Presbyterian St. Luke's Medical Center, Chicago, Illinois: Henry Black; Stanford Center for Research in Disease Prevention, Stanford University, Stanford, California: Marcia L. Stefanick; State University of New York at Stony Brook, Stony Brook, New York: Dorothy Lane; The Ohio State University, Columbus, Ohio: Rebecca Jackson; University of Alabama at Birmingham, Birmingham, Alabama: Cora Beth Lewis; University of Arizona, Tucson/Phoenix, Arizona: Tamsen Bassford; University at Buffalo, Buffalo, New York: Maurizio Trevisan; University of California at Davis, Sacramento, California: John Robbins; University of California at Irvine, Orange, California: Allan Hubbell; University of California at Los Angeles, Los Angeles, California: Howard Judd; University of California at San Diego, LaJolla/Chula Vista, California: Robert D. Langer; University of Cincinnati, Cincinnati, Ohio: Margery Gass; University of Florida, Gainesville/Jacksonville, Florida: Marian Limacher; University of Hawaii, Honolulu, Hawaii: David Curb; University of Iowa, Iowa City/Davenport, Iowa: Robert Wallace; University of Massachusetts/Fallon Clinic, Worcester, Massachusetts: Judith Ockene; University of Medicine and Dentistry of New Jersey, Newark, New Jersey: Norman Lasser; University of Miami, Miami, Florida: Mary Jo O'Sullivan; University of Minnesota, Minneapolis, Minnesota: Karen Margolis; University of Nevada, Reno, Nevada: Robert Brunner; University of North Carolina, Chapel Hill, North Carolina: Gerardo Heiss; University of Pittsburgh, Pittsburgh, Pennsylvania: Lewis Kuller; University of Tennessee, Memphis, Tennessee: Karen C. Johnson; University of Texas Health Science Center, San Antonio, Texas: Robert Schenken; University of Wisconsin, Madison, Wisconsin: Catherine Allen; Wake Forest University School of Medicine, Winston-Salem, North Carolina: Gregory Burke; and Wayne State University School of Medicine/Hutzel Hospital, Detroit, Michigan: Susan Hendrix.

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