Tea Intake Is Inversely Related to Blood Pressure in Older Women

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ABSTRACT Tea is rich in polyphenols, which have activities consistent with blood pressure–lowering potential. The effects of long-term regular ingestion of tea on blood pressure remain uncertain. We investigated the relationships of tea intake and a biomarker of exposure to tea-derived polyphenols (4-*O*-methylgallic acid) with blood pressure in a cross-sectional study of 218 women > 70 y old. Clinic blood pressures were measured and tea intake was assessed using a 24-h dietary recall; 4-*O*-methylgallic acid was measured for the same period in a 24-h urine sample. Mean (95% CI) daily tea intake was 525 (475, 600) mL. Mean systolic and diastolic blood pressures were 138.1 (135.6, 140.6) and 73.5 (72.1, 74.9) mm Hg. Higher tea intake and higher 4-*O*-methylgallic acid excretion were associated with significantly lower systolic ($P = 0.002$ and $P = 0.040$, respectively) and diastolic ($P = 0.027$ and $P < 0.001$, respectively) blood pressures. A 250 mL/d (1 cup) increase in tea intake was associated with a 2.2 (0.8, 3.6) mm Hg lower systolic blood pressure and a 0.9 (0.1, 1.7) mm Hg lower diastolic blood pressure. The observed associations for both tea intake and 4-*O*-methylgallic acid are consistent with the hypothesis that long-term regular ingestion of tea may have a favorable effect on blood pressure in older women. J. Nutr. 133: 2883–2886, 2003.

KEY WORDS: • tea • blood pressure • polyphenols • women

Apart from water, tea is the most widely consumed beverage worldwide. Therefore, any physiologic effects of drinking tea on disease risk could have important implications for population health. Results of population studies suggest that drinking tea might provide protection against coronary artery disease and stroke (1). The polyphenolic compounds found in tea are likely to be the main components responsible for any benefit (2–4). The effects of tea-derived polyphenols in improving endothelial function may be responsible at least in part for any reduction in risk (5,6). Sustained improvement in endothelial function could contribute to lower blood pressure.

The potential effect of ingestion of tea on blood pressure has been investigated in several studies (5–15). Investigations of the longer-term effects of regular ingestion of tea on blood pressure are limited to cross-sectional studies. Inverse relationships of tea intake with blood pressure (10) and the prevalence of hypertension (11) have been reported. The observed relationships of tea intake with blood pressure in other cross-sectional studies were not significant (12,13). The relationship of a biomarker of exposure to tea-derived polyphenols with blood pressure has not been previously reported.

The objective of the present analysis was to investigate the relationship of tea intake with blood pressure in a tea-drinking population of older women. In addition, given that tea polyphenols are likely to be the main components responsible for any blood pressure–lowering effect, we also investigated the relationship of 4-*O*-methylgallic acid, a biomarker of exposure to tea-derived polyphenols (16), with blood pressure.

SUBJECTS AND METHODS

Participants and design. The participants involved in this study were recruited to a 5-y, prospective, randomized, controlled trial of oral calcium supplements to prevent osteoporotic fractures in 1500 randomly selected women aged between 70 and 85 y. They were recruited from the Western Australian general population of women >70 y old by mail using the electoral roll. A random selection of 24,800 women on the electoral roll ($n = 33,366$) was sent a letter inviting participation; 5586 women (22.5%) responded, and 1510 women were willing and eligible. All participants were healthy and did not have any medical conditions likely to influence 5-y survival. The first 1500 women were randomized into the study (17,18). Although the subjects entering the study were weighted in favor of those in higher socioeconomic categories, they did not differ from the whole population in health resource utilization (17). At baseline, every third woman was asked to provide a 24-h urine collection and information about food and beverage intake using an interviewer-administered 24-h dietary recall; a total of 281 women agreed. Complete dietary information and 24-h urine collections were obtained from 275 women. All data, including dietary intake, urinary biochemical measurements, blood pressures and demographic and anthropometric factors, were available for a total of 218 women. Informed consent was obtained and the Human Rights Committee of the University of Western Australia approved the study.

Blood pressure measurement. Participants attended the clinic for blood pressure measurements. All measurements were performed in the morning after an overnight fast of at least 12 h, which included abstinence from tea, coffee and alcohol. A trained observer used a standard mercury sphygmomanometer to assess blood pressures. Participants rested in a seated position for a minimum of 5 min before blood pressure measurement commenced. Three blood pressures were then measured on the right arm at 1-min intervals. The mean blood pressure was calculated from these measurements.

Dietary assessment. During a clinic visit, food and beverage intake data were collected using an interviewer-administered 24-h

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dietary recall. All foods and beverages were recorded for the 24-h period before the clinic visit. Tea intake was assessed in milliliters and included all black tea and green tea consumed with and without additives such as milk and sugar. Tea intake was not further subcategorized because almost all tea consumed within this population was black tea with added milk. "Herbal teas" are not derived from the *Camellia sinensis* plant and therefore were not included as "tea." The food intake data were analyzed to obtain nutrient intakes using Foodworks Professional (Xyris, Brisbane Australia) based on the Australian Food Composition Database (NUTTAB 95, Australian Government Nutrient Database, Canberra, Australia).

Demographic and anthropometric factors. During a clinic visit, all participants completed a questionnaire, which collected information about age, smoking history, physical activity and residential postal code. Weight and height were measured, and the BMI was calculated in kg/m^2. Smoking status was coded into nonsmoker, ex-smoker and current smoker. For physical activity, the women filled in a questionnaire that included the following question: "Do you participate in any sports recreation or regular physical activity?" Those who answered "yes" to this question were asked to list up to four activities and the duration (in h/wk) that they engaged in each activity. Women who answered "no" to the activity question were classified as being sedentary and scored zero for activity. Activity levels in the active women were calculated in kJ/d using published energy costs of listed activities. Socioeconomic status was assessed using relative social advantage according to residential postal codes. This variable was divided into two levels: high and medium-to-low advantage.

Biochemistry. A 24-h urine sample was collected for the period corresponding to the dietary recall information. Urinary 4-*O*-methylgallic acid concentrations were used as a marker of tea-derived polyphenol intake (16). 4-*O*-Methylgallic acid was measured in urine samples using GC-MS according to a previously described method (16,19). The intra-assay variability was 5%. Urinary samples were also analyzed for sodium, potassium and creatinine using routine methods (BM/Hitachi 747 Analyzer; Boehringer-Mannheim, Mannheim, Germany).

Statistical analysis. Statistical analyses were performed using SPSS 11.5 software (Chicago, IL). Results are presented as means (95% CI), and $P < 0.05$ was the level of significance. Spearman's rank correlation was used assess the correlations between tea intake, coffee intake and 4-*O*-methylgallic acid excretion. Linear regression analysis was used to determine the relationships of predictor variables, including tea intake, 4-*O*-methylgallic acid excretion, coffee intake, alcohol intake, energy and nutrient intakes, age, BMI, smoking, physical activity, social advantage, and urinary sodium, potassium and creatinine, with the outcome variables systolic and diastolic blood pressure. Results of linear regression analyses are presented as b (95% CI). The b-value provides an estimate of the average change in blood pressure per unit increase in tea intake or 4-*O*-methylgallic acid excretion. The unit chosen for tea intake was 250 mL (1 cup), and the unit chosen for 4-*O*-methylgallic acid excretion was 1 μmol/mmol creatinine.

RESULTS

The age and BMI of the population were 74.9 (74.5, 75.3) y and 27.3 (26.7, 27.9) kg/m^2, respectively. Systolic and diastolic blood pressures were 138.1 (135.6, 140.6)/73.5 (72.1, 74.9) mm Hg. Of the population, 95% were nonsmokers, 78% were physically active and 85% had high social advantage. Tea intake was 525 (475, 600) mL, coffee intake was 300 (250, 350) mL and among alcohol drinkers mean alcohol intake was 19.6 (16.9, 22.4) g. Most of the population drank at least 250 mL of tea (76%) or coffee (65%), but most (67%) had not consumed alcohol. Of the population, ~42% drank >500 mL of tea and ~15% drank >500 mL of coffee. 4-*O*-Methylgallic acid excretion was 1.23 (0.88, 1.58) μmol/mmol creatinine. Tea intake was positively correlated with urinary 4-*O*-methylgallic acid excretion ($r = 0.62$, $P < 0.001$), and both tea intake and 4-*O*-methylgallic acid excretion were negatively correlated with coffee intake ($r = -0.45$, $P < 0.001$ and $r = -0.29$, $P < 0.001$, respectively).

Age and BMI were not associated with tea intake or 4-*O*-methylgallic acid excretion. Age was not associated with systolic blood pressure [b-value 0.14 (−0.81, 1.09), $P = 0.77$], but was inversely associated with diastolic blood pressure [−0.53 (−1.07, −0.01), $P = 0.049$]. Positive associations with systolic and diastolic blood pressure were found for BMI [0.83 (0.29, 1.37), $P = 0.003$ and 0.41 (0.10, 0.71), $P = 0.01$, respectively]. There was a nonsignificant trend for higher coffee intake to be associated with higher systolic and diastolic blood pressures [0.97 (−0.93, 2.86), $P = 0.07$ and 0.98 (−0.09, 2.05), $P = 0.07$], respectively). Energy and nutrient intakes, alcohol intake, urinary sodium, potassium and creatinine, smoking, physical activity and social advantage were not associated with blood pressure.

There was a linear trend for systolic and diastolic blood pressures to be lower with higher tea intakes ($P = 0.001$ and $P = 0.015$, respectively) and higher 4-*O*-methylgallic acid excretion ($P = 0.008$ and $P < 0.001$, respectively) (**Fig. 1**). In univariate and adjusted multivariate models, higher tea intake and higher 4-*O*-methylgallic acid excretion were associated with significantly lower systolic and diastolic blood pressure (**Table 1**). Univariate associations were largely unchanged after adjustment for coffee and alcohol intake, age, BMI, smoking, physical activity and social advantage. The small reduction in b-values observed in multivariate analysis was due primarily to the presence of coffee intake in the model (**Table 1**). Further adjustment for energy and nutrient intakes, and urinary sodium, potassium and creatinine did not further alter the relationships.

DISCUSSION

In a cross-sectional study of an older population of tea-drinking women, we report inverse relationships of tea intake and urinary 4-*O*-methylgallic acid with systolic and diastolic

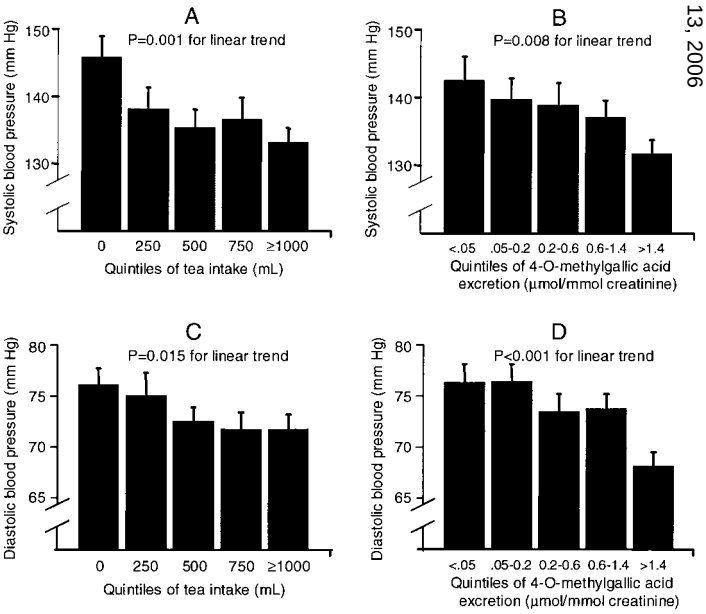

FIGURE 1. Systolic blood pressures (*panels A* and *B*) and diastolic blood pressures (*panels C* and D) according to quintiles of tea intake (*panels A* and *C*) and 4-*O*-methylgallic acid excretion (*panels B* and *D*) in a cross-sectional study of 218 women aged 70–85 y. *P*-values are for linear trend analyzed using linear regression

TABLE 1

Univariate and adjusted multivariate relationships of tea intake and urinary 4-O-methylgallic acid with blood pressure in 218 women aged 70–85 y[1]

	Systolic blood pressure (mm Hg)		Diastolic blood pressure (mm Hg)	
	b (95% CI)	*P*-value	b (95% CI)	*P*-value
Univariate				
Tea intake (per 250 *mL*)	−2.2 (−3.6,−0.8)	0.002	−0.9 (−1.7,−0.1)	0.027
4-*O*-Methylgallic acid (per 1 *μmol/mmol* creatinine)	−1.0 (−1.9,−0.1)	0.040	−1.1 (−1.6,−0.5)	<0.001
Multivariate[2]				
Tea intake (per 250 *mL*)	−2.0 (−3.6,−0.4)	0.015	−0.7 (−1.6, 0.2)	0.15
4-*O*-Methylgallic acid (per 1 *μmol/mmol* creatinine)	−0.8 (−1.8, 0.2)	0.10	−1.0 (−1.5,−0.5)	<0.001

[1] Results are presented as change in blood pressure (b and 95% CI) per 250 mL (1 cup) increase in tea intake or 1 μmol/mmol creatinine increase in 4-*O*-methylgallic acid excretion.

[2] Adjusted by linear regression for coffee and alcohol intake, age, BMI, smoking, physical activity and social advantage.

blood pressures. A 250-mL (1 cup) increase in tea intake was associated with a 2.2 mm Hg lower systolic blood pressure and a 0.9 mm Hg lower diastolic blood pressure. These relationships were largely unchanged after adjustment for potential confounders. The magnitude of these estimated decreases in blood pressure might be interpreted in terms of their potential effect on hypertension and cardiovascular disease. Population-wide decreases in blood pressure of 2–3 mm Hg are likely to result in a 17% decrease in the prevalence of hypertension, a 6% decrease in risk of coronary artery disease and a 15% decrease in risk of stroke (20).

Several studies have investigated the potential effects of ingestion of tea on blood pressure (5–15). Experimental studies in humans show that ingestion of tea can cause a transient increase in blood pressure, an effect due primarily to caffeine (8,14). Feeding trials in rats are suggestive of a depressor effect of tea (15). Randomized controlled intervention trials that have found no effect of regular ingestion of tea on blood pressure have been short term, for up to 4 wk (5–9) and included mostly men (5,6,8,9). Longer-term effects on vasodilator function (5,6) may be necessary to alter vascular tone and blood pressure.

The few population studies that have investigated the relationship between long-term tea intake and blood pressure have been cross sectional (10,12,13). A significant inverse relationship between tea intake and blood pressure, which was stronger for women, was found in one study (10). More recently, a significant inverse association between tea intake and prevalence of hypertension was observed. Gender differences were not investigated in this study (11). Other cross-sectional studies showing nonsignificant inverse relationships between tea intake and blood pressure have not included women (13) or have not analyzed men and women separately (12).

Our study is the first to investigate the relationship of a marker of tea-derived polyphenols with blood pressure. We suggest that polyphenols, which are present at high concentrations in tea, may account at least in part for any favorable effect on blood pressure. We measured 24-h urinary 4-*O*-methylgallic acid excretion as a marker of exposure to tea-derived polyphenols. We showed previously that 24-h urinary 4-*O*-methylgallic acid excretion provides a good indication of polyphenol exposure, i.e., intake and absorption, from tea (16) and may provide an indication of polyphenol metabolism (21). The observed inverse relationship between 4-*O*-methylgallic acid excretion and blood pressure is consistent with the hypothesis that polyphenols are responsible for any favorable effects of tea on blood pressure.

If tea-derived polyphenols can benefit blood pressure, what might be the mechanisms? The effects of polyphenols in improving endothelial function may be at least partially responsible (5,6). Many of the polyphenols in tea have potent antioxidant activity in vitro (22) and possibly in vivo (19,23). Particular polyphenols present in tea have been found to exhibit estrogen-like activity in vitro (24) and in vivo (25). Polyphenols in tea may improve endothelial function via antioxidant (26,27) and estrogen-like activity (28).

In conclusion, we observed inverse relationships for both tea intake and 4-*O*-methylgallic acid excretion with blood pressure in older women. The results are consistent with the suggestion that any postulated blood pressure–lowering effect of tea may be due to tea-derived polyphenols, and are consistent with the hypothesis that long-term regular ingestion of tea may have a beneficial effect on blood pressure in this population. Long-term intervention studies are warranted to clarify the potential influence of regular ingestion of tea on blood pressure.

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