

# The Protective Effect of Habitual Tea Consumption on Hypertension

Yi-Ching Yang, MD, MPH; Feng-Hwa Lu, MD, MS; Jin-Shang Wu, MD; Chih-Hsing Wu, MD; Chih-Jen Chang, MD

**Background:** Tea has long been believed to possess hypotensive effects in popular Chinese medicine. However, conflicting results have been shown among human trials and animal studies on the relation between tea consumption and blood pressure. Epidemiological evidence about the long-term effect of tea on hypertensive risk is also inconsistent.

**Methods:** We examined the effect of tea drinking, measured in detail for the past decades, on the risk of newly diagnosed hypertension in 1507 subjects (711 men and 796 women), 20 years or older, who did not have a hypertensive history during 1996 in Taiwan.

**Results:** Six hundred subjects (39.8%) were habitual tea drinkers, defined by tea consumption of 120 mL/d or more for at least 1 year. Compared with nonhabitual tea drinkers, the risk of developing hypertension decreased by 46%

for those who drank 120 to 599 mL/d and was further reduced by 65% for those who drank 600 mL/d or more after carefully adjusting for age, sex, socioeconomic status, family history of hypertension, body mass index, waist-hip ratio, lifestyle factors (total physical activity, high sodium intake, cigarette smoking, alcohol consumption, and coffee drinking), and dietary factors (vegetable, fruit, unrefined grain, fish, milk, visible-fat food, and deep fried food intake). However, tea consumption for more than 1 year was not associated with a further reduction of hypertension risk.

**Conclusion:** Habitual moderate strength green or oolong tea consumption, 120 mL/d or more for 1 year, significantly reduces the risk of developing hypertension in the Chinese population.

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**T**EA, HAVING BEEN BREWED from the leaves of the *Camellia sinensis* for almost 4000 years, is the most popularly consumed beverage worldwide, second only to water, with a per capita worldwide consumption of approximately 0.12 L/y.<sup>1</sup> Owing to the high consumption of tea, even small effects in persons could have a large effect on public health. Tea contains more than 4000 chemical compounds that may affect the human body in many aspects.<sup>2,3</sup> There has been a growing interest in recent years in exploring the preventive effect of tea, especially polyphenolic flavonoids in tea, against cardiovascular diseases (CVDs)<sup>4-8</sup> and the development and progression of atherosclerosis.<sup>9,10</sup> The delicate mechanisms responsible for the benefits of tea with regard to cardiovascular risk are, however, unclear.

Hypertension is the most common form of CVD, affecting millions of people throughout the world and about 20% of

the adult population in many countries. It is interrelated with coronary artery disease, stroke, congestive heart failure, and renal dysfunction, and is one of the major risk factors for cardiovascular-related mortality, which accounts for 20% to 50% of all deaths.<sup>11</sup> A link between tea drinking and blood pressure reduction has been postulated for decades in general health care in Chinese populations.<sup>12</sup> However, there are few studies regarding the long-term effect of tea drinking on the risk of hypertension, and the results of the few studies investigating the relation between tea consumption and blood pressure were rather conflicting. In epidemiological studies, a higher consumption of black tea in Norwegian men and women was associated with a lower systolic blood pressure (SBP),<sup>13</sup> while green tea intake in middle-aged Japanese self-defense officials was unrelated to blood pressure.<sup>14</sup> In animal studies,<sup>15-19</sup> several Japanese researchers consistently noted that green tea extracts exhibit a substantial hypotensive effect in rats. On the contrary, in hu-

From the Department of Family Medicine, Medical College, National Cheng Kung University, Tainan, Taiwan. The authors have no relevant financial interest in this article.

man clinical trials, 5 cups of either green or black tea daily for 1 week did not significantly alter the ambulatory blood pressure of 13 normotensive Australian men,<sup>20</sup> nor did 6 cups a day of black tea for 4 weeks in a study of 57 men and women in England.<sup>21</sup> However, comprehensive information about tea consumption was not collected, and potential confounding lifestyle and dietary factors were not extensively measured, in the previously cited epidemiological studies. Although the findings of animal studies cannot be necessarily extrapolated to humans, the long-term effects of tea on blood pressure also cannot be ruled out by the results of short-term clinical trials. Therefore, we examined the long-term effects of tea drinking measured in detail on the risk of newly diagnosed hypertension, taking into account the potential confounding factors of lifestyle and dietary factors in addition to the traditional risk factors of hypertension, in an epidemiology-based Chinese adult population in Taiwan.

## METHODS

### SUBJECTS AND DATA COLLECTION

The subjects were participants in a community-based study for chronic diseases conducted in Tainan, the oldest city in southern Taiwan, with a population of 700 000. Details of the study have been described elsewhere.<sup>22</sup> Briefly, in 1996, 2416 eligible Chinese subjects (48.4% men) were selected by a stratified systemic cluster sampling method from 7 administrative districts throughout Tainan. The sampling scheme was a 3-stage process that generated a stratified systemic cluster sample of households throughout the city. First, areas of the city were grouped into 7 strata according to the administrative districts. One area (Li, an administrative unit, subdivided from districts of the city) was randomly selected from each stratum. Second, every fifth household within each of the 7 selected areas was identified systematically. Third, the selected households were informed about the survey by letter and telephone from the medical center to seek consent for participation and to arrange the schedule of examinations. All subjects 20 years or older according to the government population register in 1995 were included in the study. From January 15, 1996, to December 1, 1996, 1638 participants 20 years or older (47.6% men) finished a screening health examination, with a response rate of 67.8%. The nonresponders were slightly younger and consisted of more men compared with the responders, but the differences were not statistically significant. Written consents were obtained from all the participants, and the research committee of National Cheng Kung University Hospital approved this study.

All subjects were interviewed by a well-trained assistant, using a structured questionnaire, which included demographic information, medical history of hypertension, medication history, smoking habit, coffee and alcohol drinking habit, food frequency questionnaires, physical activity during the past year, and family history of hypertension. Subjects with a history of hypertension who were receiving antihypertensive treatment were excluded. Once a patient is diagnosed as having hypertension, the patient might change his or her lifestyle or other relevant factors. A family history positive for hypertension was defined when subjects reported hypertension in their first-degree relatives. Five levels of socioeconomic status were determined by the Hollingshead Two Factor Index of Social Position. The index was based on the cross classification of educational level and occupation of the primary breadwinner in the family of origin.<sup>23</sup>

## ANTHROPOMETRIC AND BLOOD PRESSURE MEASUREMENTS

All measurements were performed using standard methods by physicians (Y.-C.Y., J.-S.W., and C.-H.W.) or well-trained nurses. The body mass index, an index of general obesity, was calculated as weight in kilograms divided by the square of height in meters. Waist (midway between the lower rib margin and the iliac crest) and hip (over the greater trochanters) circumferences were measured in duplicate, with the undressed participant standing at the end of normal expiration. The waist-hip circumference ratio was calculated as an index of central obesity. Two readings of SBP and diastolic blood pressure (DBP) were measured in the supine position with a vital sign monitor (model 1846SX, DINAMAP; Critikon Inc, Irvine, Calif)<sup>24</sup> after at least 15 minutes of resting. Hypertension was defined according to the criteria suggested in the Sixth Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure<sup>25</sup>: a mean SBP of 140 mm Hg or higher, a mean DBP of 90 mm Hg or higher, or a history of hypertension and currently receiving treatment.

### ASSESSMENT OF LIFESTYLE AND DIETARY FACTORS

Participants were asked about the type, duration, and weekly frequency of all kinds of physical activity, including work-related, household, and leisure time physical activity (including walking), in the past year. The total physical activity assessment was calculated by summing the average metabolic equivalent hour per week over each activity for the past year.<sup>22,26,27</sup> The risk of exposure to smoke was quantified by multiplying the amount of cigarettes smoked by the duration of cigarette smoking, expressed as pack-years. Cigarette smoking was dichotomized by the cutoff of 10 pack-years.<sup>28</sup> For an alcohol consumption estimation, a quantity-frequency-duration measure (including items about types of alcoholic beverage, frequency per week, and usual amount consumed each time in different kinds of alcoholic beverage) was administered and the average weekly absolute alcohol intake in grams of ethanol was calculated. Alcohol drinking was also dichotomized by the cutoff of 60 g/wk for 5 years. High sodium intake behaviors were evaluated by summing the frequency of 4 kinds of behaviors in 1 week: traditional salted food intake, extra table salt or sodium content sauces used, restaurant meals, and fast food intake.<sup>29</sup> Furthermore, a semi-quantitative food frequency questionnaire was applied to assess average dietary intake during the past year. Seven frequency categories were as follows: less than once a month, 1 to 3 times per month, 1 to 2 times per week, 3 to 6 times per week, 1 to 2 times per day, 3 to 5 times per day, and 6 times or more per day. Dietary factors include vegetables, fruits, unrefined grains (cereal, oatmeal, or wheat), fish, milk, coffee, deep fried foods, and food with visible fat (bacon or chicken skin).

### ASSESSMENT OF TEA CONSUMPTION

In Chinese culture, the size of a teacup varies widely, depending on the different situations, needs, and purposes. The spectrum of volume can vary from 30 mL per cup in traditional so-called elderly tea, 150 mL per cup in a typical western restaurant for afternoon tea, 250 mL per cup in a mug, 300 mL per pack in aluminum foil packing tea, 350 mL per can in canned tea, 500 mL in handy bottled tea, and up to 600 to approximately 750 mL in an extra large plastic cup in a tea shop. Subjects were asked in detail about what kind of cup was used, the method for preparing tea extracts, the amount of tea consumption each time, and the frequency per week to calculate as exactly as possible the average amount of daily tea consumption. Other information about the kind of tea (green, black, or oolong), milk

**Table 1. Basic Characteristics of the Study Population According to Tea Consumption\***

Characteristic	Total (N = 1507)	Tea Consumption, mL/d		
		<120 (n = 878)	120-599 (n = 436)	≥600 (n = 193)
Male sex	47.2	40.4	55.7	61.5†
Age, y‡	42.2 (14.8)	43.0 (15.1)	40.8 (14.1)§	41.3 (14.4)§
Educational level, <6/6-11/≥12 y	30.5/40.8/28.1	35.8/36.7/27.4	22.2/46.5/31.3	24.7/50.5/25.3†
Socioeconomic status level, I/II/III-V	18.8/44.7/35.5	24.4/43.4/32.2	9.7/49.4/40.9	13.4/44.1/42.5†
Body mass index‡¶	23.6 (3.6)	23.4 (3.6)	23.7 (3.5)	24.1 (3.6)§
Waist-hip ratio‡	0.85 (0.09)	0.84 (0.09)	0.85 (0.09)	0.86 (0.08)§
Blood pressure, mm Hg‡				
Systolic	115.8 (17.3)	116.8 (18.3)	114.2 (15.8)§	114.7 (15.3)§
Diastolic	70.1 (9.9)	70.3 (9.9)	69.7 (9.7)	69.6 (10.1)
Those with newly diagnosed hypertension during the study	10.9	12.8	8.4	7.1#
Lifestyle factors				
Total physical activity, MET h/wk‡	58.6 (57.3)	56.7 (54.7)	59.6 (57.6)	65.8 (67.5)§
High sodium intake, times/wk‡	9.2 (9.8)	8.2 (7.9)	10.2 (9.1)**	11.9 (16.8)§
Tea drinking, mL/d‡	216.0 (392.5)	2.5 (12.7)	276.4 (134.4)**	1107.8 (414.7)**
Alcohol drinking, ≥60 g/wk for ≥5 y	8.0	5.2	12.7	12.1†
Coffee drinking, daily	5.0	4.2	7.2	4.4
Cigarette smoking, ≥10 pack-years	16.1	10.6	20.8	34.4†
Dietary factors				
Vegetables, daily	78.1	80.3	75.1	74.2#
Fresh fruits, daily	56.4	57.4	52.6	59.9
Unrefined grain, daily	7.4	8.3	6.7	4.9
Fish, daily	46.8	48.4	44.5	44.0
Milk, daily	33.5	34.5	31.8	32.4
Egg, ≥3 times/wk	39.2	37.2	43.3	39.6
Visible-fat food, ≥3 times/wk	13.1	13.1	12.2	15.4
Deep fried food, ≥3 times/wk	12.9	11.8	15.6	12.6
Tea drinking variables				
Green or oolong tea	NA	NA	96.7	95.6
Milk addition	NA	NA	5.3	3.8

Abbreviations: MET, metabolic equivalent; NA, data not available.

\*Data are given as percentage of subjects in each group unless otherwise indicated.

† $P < .001$ ,  $\chi^2$  analysis.

‡Data are given as mean (SD).

§ $P < .05$ , analysis of variance with a post hoc test, using those who consumed less than 120 mL/d as the reference.

||The percentages within each group may not total 100 because of rounding.

¶Calculated as weight in kilograms divided by the square of height in meters.

# $P < .05$ ,  $\chi^2$  analysis.

\*\* $P < .001$ , analysis of variance with a post hoc test, using those who consumed less than 120 mL/d as the reference.

or sugar addition, and the duration of the tea drinking habit was also collected in detail.

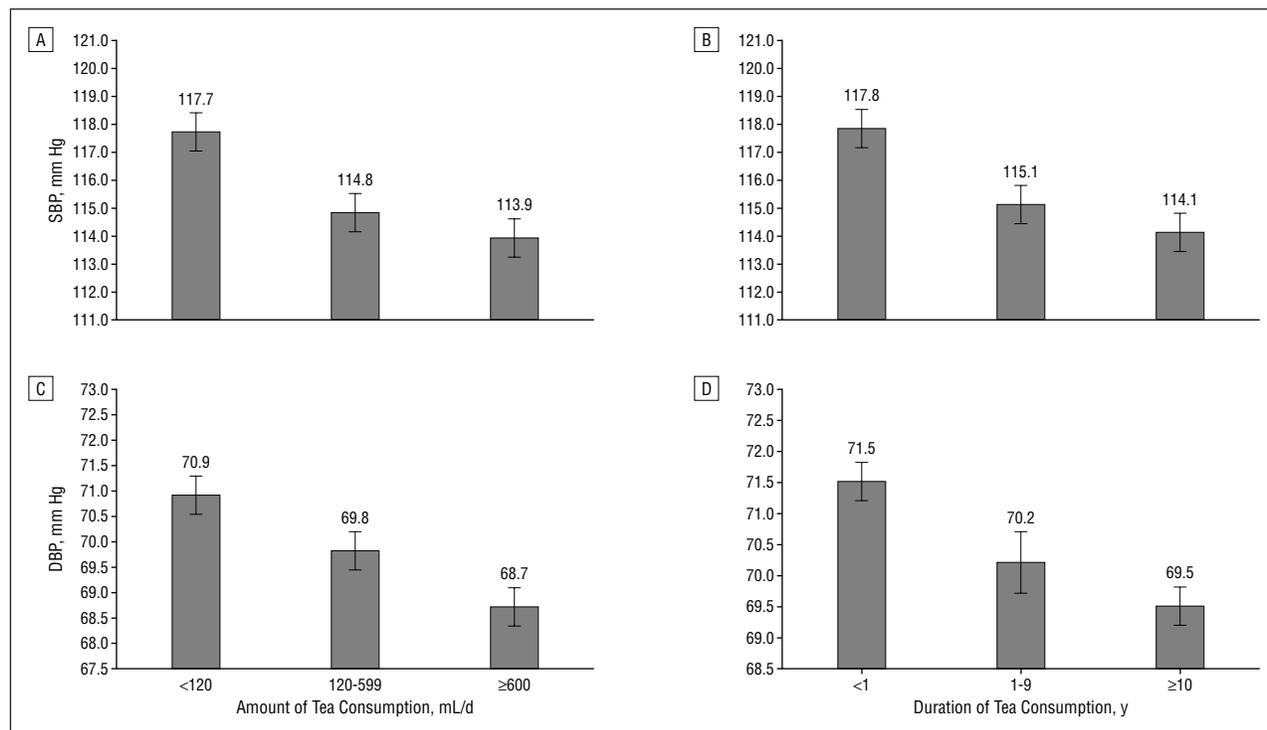
#### DATA ANALYSIS

Data were analyzed using a commercially available statistical software program (SPSSWIN, version 10.0; SPSS Inc, Chicago, Ill). We categorized subjects into 3 subgroups according to the average amount of daily tea consumption: nonhabitual (<120 mL/d), between 120 and 599 mL/d, and 600 mL/d or more. The  $\chi^2$  and analysis of variance methods were applied to compare the distribution of lifestyles and selected dietary factors among groups to identify potential confounders, because a health behavior aggregating tendency was noted. The differences in SBP and DBP among the 3 subgroups were subjected to an analysis of covariance, which also adjusted for all the previously described covariates, and expressed as figures. Categories of tea intake were entered into a multivariable logistic regression model, with newly diagnosed hypertension as the dependent variable. We analyzed the independent effects of tea consumption, with stepwise adjustment of several known risk factors for hypertension and lifestyle and dietary factors. Each

independent variable was expressed with an odds ratio (OR) and 95% confidence interval. Statistical significance was defined as  $P < .05$  for 2-tailed analysis.

#### RESULTS

Of the 1507 subjects without a history of hypertension, 39.8% drank at least 120 mL/d for 1 or more years. These habitual tea drinkers were younger, predominantly men, and had higher educational and socioeconomic levels. They were more generally and centrally obese. They smoked more, consumed more alcohol, ate fewer vegetables, and had more frequent high sodium intake. Other factors related to lifestyle (total physical activity and coffee drinking) and diet (fruit, unrefined grain, fish, milk, visible-fat food, and deep fried food intake) were not associated with tea drinking. On the contrary, these habitual tea drinkers had lower mean SBPs and a lower prevalence of newly diagnosed hypertension than nonhabitual tea drinkers (**Table 1**). Among the 600 ha-



Dose-response effect between the amount and duration of tea consumption and blood pressure. A, Amount of tea consumption and mean systolic blood pressure (SBP). There were significant differences between nonhabitual consumers and those consuming 120 to 599 mL/d ( $P=.002$ ) and those consuming 600 mL/d or more ( $P=.003$ ). B, Duration of tea consumption and SBP. There were significant differences between nonhabitual consumers and those consuming tea for 1 to 9 years ( $P=.003$ ) and 10 years or more ( $P=.004$ ). C, Amount of tea consumption and diastolic blood pressure (DBP). There were significant differences between nonhabitual consumers and those consuming 120 to 599 mL/d ( $P=.03$ ) and those consuming 600 mL/d or more ( $P=.003$ ). D, Duration of tea consumption and DBP. There were significant differences between nonhabitual consumers and those consuming tea for 1 to 9 years and 10 years or more ( $P=.01$  for both). An analysis of covariance was performed, adjusted for age, sex, family history of hypertension, body mass index, waist-hip ratio, socioeconomic status, total physical activity, high sodium intake, smoking, alcohol drinking, and coffee, fruit, vegetable, unrefined rice, fish, milk, visible-fat food, and deep fried food intake. Data are given as the adjusted mean  $\pm$  SE.

bitual tea drinkers, 96.3% were green or oolong tea drinkers and only 4.8% had the habit of adding milk during tea consumption.

In the **Figure**, negative linear effects correlating to the amount and duration of tea consumption were found for the SBP and the DBP of our subjects. After adjustment for age, sex, body mass index, waist-hip circumference ratio, family history of hypertension, socioeconomic status, and 5 lifestyle and 7 dietary covariates, the adjusted mean SBP and DBP values were lowest among the subjects who drank 600 mL/d or more or those who drank for 10 years or more compared with the other 2 subgroups. Although the differences in SBP and DBP were small, these could be significant on a population-wide basis.

The results of a multiple logistic regression analysis assessing the risk of newly diagnosed hypertension associated with different categories of tea consumption by amount are given in model 1 of **Table 2**. Compared with nonhabitual tea drinkers, the risk of developing hypertension decreased by 46% for those who drank 120 to 599 mL/d, and was further reduced by 65% for those who drank 600 mL/d or more, when we adjusted using 5 covariates for lifestyle (total physical activity, high sodium intake, cigarette smoking, alcohol drinking, and coffee consumption) and 7 selected dietary factors (vegetable, fruit, unrefined grain, fish, milk, food with visible fat, and deep fried food intake) in addition to the tradi-

tional major risk factors for hypertension (age, sex, family history of hypertension, body mass index, waist-hip circumference ratio, and socioeconomic status). When we considered the duration of tea consumption instead of the amount of tea consumption on the risk of newly diagnosed hypertension, the risk for hypertension was still significantly lower in those who drank tea for more than 1 year when comparing with the non-tea drinkers or those who drank tea for less than 1 year. However, increasing the duration of tea consumption for 10 years or more did not offer extra protection against the risk of developing hypertension (the OR for those who had drunk for 1-9 years vs those who had drunk for  $\geq 10$  years was similar, as shown in model 2 of Table 2: 0.54 vs 0.55). When we used amount and duration of tea consumption in a regression model, compared with nonhabitual tea drinkers, the OR of newly diagnosed hypertension for those who drank 120 to 599 mL/d was 0.19 and the OR for those who drank 600 mL/d or more was lower, 0.13. However, the duration of tea consumption no longer played a significant role in the hypertension risk (model 3 in Table 2).

#### COMMENT

In contrast to the results from short-term clinical trials,<sup>20,21</sup> we observed a negative linear trend of multi-adjusted mean blood pressure with increasing tea con-

**Table 2. Multiple Logistic Regression Models of Tea Consumption of the Hypertensive Subjects Who Were Newly Diagnosed During the Study**

Variable	Model*		
	1	2	3
Amount of tea consumption, mL/d			
<120	1.00	NA	1.00
120-599	0.54 (0.34-0.86)†	NA	0.19 (0.04-0.85)†
≥600	0.35 (0.17-0.73)†	NA	0.13 (0.03-0.61)†
Duration of tea consumption, y			
<1	NA	1.00	1.00
1-9	NA	0.54 (0.33-0.88)†	2.84 (0.64-12.58)
≥10	NA	0.55 (0.31-1.00)†	3.13 (0.67-14.50)
Age	1.07 (1.05-1.09)‡	1.07 (1.05-1.09)‡	1.07 (1.05-1.09)‡
Sex, men vs women	1.45 (0.83-2.54)	1.43 (0.82-2.49)	1.46 (0.84-2.55)
Family history of hypertension, yes vs no	1.70 (1.11-2.60)†	1.69 (1.10-2.59)†	1.71 (1.11-2.63)†
Body mass index	1.18 (1.11-1.25)‡	1.17 (1.10-1.25)‡	1.18 (1.11-1.25)‡
Waist-hip ratio × 100	1.02 (0.98-1.05)	1.02 (0.98-1.05)	1.02 (0.98-1.05)
Socioeconomic status level			
II vs III-V	1.14 (0.64-2.05)	1.15 (0.64-2.07)	1.18 (0.65-2.12)
I vs III-V	1.30 (0.81-2.09)	1.30 (0.81-2.10)	1.33 (0.82-2.14)
Tertile of total physical activity			
Middle vs lowest	0.80 (0.50-1.27)	0.79 (0.50-1.26)	0.80 (0.50-1.27)
Highest vs lowest	0.95 (0.60-1.50)	0.93 (0.59-1.47)	0.96 (0.61-1.52)
High sodium intake, ≥14 times/wk vs less	1.14 (0.68-1.93)	1.10 (0.66-1.87)	1.15 (0.68-1.94)
Habitual cigarette smoking, yes vs no	1.10 (0.66-1.86)	1.07 (0.64-1.79)	1.06 (0.63-1.79)
Habitual alcohol drinking, yes vs no	1.05 (0.55-2.01)	1.06 (0.55-2.03)	1.04 (0.54-2.01)
Habitual coffee intake, yes vs no	0.71 (0.30-1.67)	0.69 (0.29-1.63)	0.71 (0.30-1.67)
Vegetable consumption, yes vs no	0.57 (0.89-0.93)†	0.58 (0.35-0.95)†	0.55 (0.33-0.91)†

Abbreviation: NA, data not available.

\*Data are given as odds ratio (95% confidence interval). Models 1 and 2 used amount and duration of the tea consumption, respectively, and model 3 used both variables. All 3 models also had the following factors adjusted: fruit, unrefined rice, fish, milk, visible-fat food, and deep fried food consumption.

† $P < .05$ .

‡ $P < .001$ .

sumption and an inverse association between the newly diagnosed hypertension risk and tea consumption of at least 120 mL/d for 1 year. Nonhabitual tea drinkers were at higher risk of hypertension than habitual tea drinkers, and there was a progressive reduction in risk associated with higher levels of tea consumption in daily intake. From the several models launched in this study, we hypothesize that the threshold of tea consumption likely to be beneficial for reducing the hypertension risk is to consume green or oolong tea, 120 mL/d or more, for at least 1 year.

There are several methodological issues that need to be discussed herein before accepting these preliminary findings. As we scrutinize the discrepancy of studies exploring the relation of CVD and tea consumption, the inconsistency between these studies may be largely due to the confounding presented by different weighting of socioeconomic and lifestyle factors associated with tea drinking in the respective region based on different cultures.<sup>30</sup> Tea consumption was positively associated with a higher educational level and a healthy lifestyle in the Netherlands,<sup>3</sup> Japan,<sup>10,31</sup> Austria,<sup>32</sup> and the United States,<sup>33</sup> but those who drink tea in Wales<sup>34</sup> and Scotland<sup>35</sup> tend to be less educated, smoke more, and consume more fat. The previous conflicting results of tea consumption on blood pressure, as described in Norway, the United States, and Japan, might be due to the uncontrolled confounding factors.<sup>13,14,36,37</sup> Therefore, when the health effect of tea is examined using observational studies, it is neces-

sary to consider potential confounding and effect modification by other lifestyle and dietary factors. Although cigarette smoking is thought to be an unhealthy habit, while tea drinking is frequently regarded as a healthy behavior in Chinese persons, there was a positive cigarette-alcohol-tea aggregation found in our study subjects and in other Chinese populations.<sup>38</sup> The possible explanation is that, because of the traditional health conscious label of tea, habitual alcohol drinkers and cigarette smokers might be prone to adapt a more positive behavior like tea drinking to counteract the detrimental effect of their negative behaviors. An additional reason was that those 3 habits are common social media, which might frequently be used in either formal banquets or informal chit-chat. As described in the "Results" section, several lifestyle and dietary factors indeed confound the association between tea drinking and hypertension, but the ORs do not seem to change a lot when gradually adjusting for other factors.

A Norwegian cross-sectional study showed that the adjusted mean SBP decreased with increasing tea consumption, with a significant linear trend when there was a difference of 2.1 and 3.5 mm Hg between non-tea drinkers and those who drank more than 5 cups in men and women, respectively. However, the subjects with a history of hypertension were not excluded for analysis, and only 1.4% of men and 0.8% of women drank 5 or more cups per day in this study.<sup>13</sup> The estimates in the study could be biased in subjects who were aware of an in-

creased risk of CVD and intentionally changed their diet or lifestyle toward a healthier one. We avoided this type of bias by excluding subjects with a high blood pressure history and/or those receiving antihypertensive medication, and analyzed only those with newly diagnosed hypertension using multivariate adjustment.

When studying chronic diseases like hypertension, long-term diet rather than recent dietary intake is the relevant strategy. We used a semiquantitative food frequency questionnaire to assess the diet consumed by the study subjects during the past year. Adults have a stable nutrient intake during many years.<sup>39</sup> The proportion of misclassification in long-term dietary intakes is small, so this would not have had a large effect on our findings. We took these dietary factors into consideration in our model, and vegetable consumption produced a significantly inverse association with hypertension prevalence in our study, which is compatible with previous studies.<sup>40</sup> Other major well-known hypertension risk factors, including age, family history of hypertension, and body mass index, found in our study were consistent with those found in previous articles,<sup>40-42</sup> which suggested that our study population is not a unique group and that our findings could be extrapolated to other populations.

Through what possible mechanism might tea extracts affect blood pressure? From the present investigated physiological and pharmacological action of various components of tea, caffeine is well-known to have a short-term pressor effect following immediate tea ingestion within 30 minutes, but this effect will not translate into significant alterations 60 minutes later.<sup>21</sup> Another potentially interesting component of tea with respect to blood pressure is theanine ( $\gamma$ -glutamylethylamide), which is one of the major components of amino acids in green tea and one of the neurotransmitters in the brain. Theanine administration to spontaneously hypertensive rats significantly reduced blood pressure; however, the exact reason is still not fully understood.<sup>18,19</sup> The possible hypothesis could be the antioxidant and vasodilatory effect of polyphenols in tea.<sup>43,44</sup> Hypertension is characterized by increased peripheral vascular resistance and may, therefore, be associated with endothelial dysfunction through either loss of endothelium-dependent vasodilator activity or enhanced endothelium-dependent vasoconstriction. Oxidative stress has been implicated in the pathophysiological features of some CVDs, including hypertension and atherosclerosis.<sup>45</sup> Thus, it has been proposed that impairment of nitric oxide synthesis, or increased inactivated nitric oxide by superoxide radicals, may account for the increased peripheral vascular tone associated with hypertension. There has been much evidence demonstrated *in vitro* and *in vivo* that tea polyphenols possess a strong antioxidant effect.<sup>44,46</sup> Among various plant extracts of vegetables, fruits, teas, nuts, herbs, and spices, the top 5 that exhibited the greatest relaxing ability of vascular smooth muscle are cinnamon, peanut skin, red apple skin, guava pulp, and green tea.<sup>44</sup> Accordingly, the endothelial dysfunction in the pathogenesis of hypertension may be reversed by the antioxidant-rich and vascular smooth muscle-relaxing tea extracts.<sup>47</sup> A recent study<sup>48</sup> showed that 4 weeks of black tea consumption improved endothelium-dependent flow-mediated dilation of the bra-

chial artery in patients with coronary artery disease. Furthermore, a similar trial<sup>49</sup> of subjects with only mild dyslipidemia showed an additional endothelium-independent dilatation effect of tea consumption. These findings suggested another mechanism by which tea may prevent CVD, including hypertension, via improved vasodilator function of conduit arteries.

However, the doses required for demonstrating short-term reduction of blood pressure in animal studies are much higher than the amounts consumed by humans who drink tea. This might partially explain the discrepancy of findings between animal studies and human clinical trials, and we presume that an adequate amount of tea consumed for a sufficient duration might be needed to demonstrate the long-term blood pressure-lowering effect in habitual tea drinkers.

To the best of our knowledge, this is the first study on the relationship between hypertension risk and tea consumption using detailed quantitative and qualitative information with multiple adjusted lifestyle and dietary factors. In this study, we noted a comprehensive link between lifestyle factors and tea consumption and improved control for potential confounders and measurement of the many characteristics of tea, including duration and amount of consumption in detail. Although this is only a cross-sectional study, we made up for the weakness of the study by excluding the subjects with a hypertension history and querying about the tea consumption, lifestyle, and dietary behavior during past years to lengthen the effective time sequence. The possible protective effects of tea consumption on hypertension risk have been suggested by our epidemiological study, and the possible blood pressure-lowering effect and mechanism of tea extracts were supported by some animal laboratory studies. However, more evidence from a long-term, randomized, prospective study is needed to fortify our preliminary inference about the link between tea consumption and hypertension risk.

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Correspondence: Chih-Jen Chang, MD, Department of Family Medicine, National Cheng Kung University Hospital, 138 Sheng-Li Rd, Tainan 70428, Taiwan (em75210@email.ncku.edu.tw).

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