Relation of Green Tea Consumption to Serum Lipids and Lipoproteins in Japanese Men

Suminori Kono 1, Koichi Shinchi 1, Kazuo Wakabayashi 2, Satoshi Honjo 2, Isao Todoroki 2, Yutaka Sakurai 2, Koji Imanishi 3, Hiroshi Nishikawa 4, Shinsaku Ogawa 5, and Mitsuhiko Katsurada 5

Animal experiments have shown a hypocholesterolemic effect of green tea extracts. Only few epidemiological studies have addressed the relation between green tea consumption and serum total cholesterol (TC) and low density lipoprotein cholesterol (LDL-C). This paper examined the relation of green tea consumption to serum lipids and lipoproteins in 2,062 male self-defense officials in Japan, aged 49-55 years, who received a preretirement health examination at three hospitals of the Self-Defense Forces in 1991-1992. A self-administered questionnaire queried the consumption of green tea and a limited number of other dietary items as well as lifestyle characteristics. After adjustment for body mass index, waist-hip ratio, smoking, alcohol use, exercise, rank, and hospital, green tea consumption was inversely associated with serum levels of TC and LDL-C, but not with either high density lipoprotein cholesterol or triglycerides. Rice consumption was positively correlated with green tea consumption, and also was associated independently with lower levels of TC and LDL-C. Additional adjustment for rice, however, did not change the results. Daily drinking of 10 cups of green tea was associated with differences of 6.2 mg/dl in TC (95% confidence interval [CI] 0.4-12.1) and 6.2 mg/dl in LDL-C (95% CI 0.7-11.7). These findings of association of green tea with blood cholesterol hint at a possible causal relationship, which requires confirmation by further studies in humans using different methods. 

J Epidemiol, 1996; 6: 128-133.

Hypercholesterolemia is an important risk factor of coronary heart disease not only in Western countries 4 but also in Japan 5. Thus the prevention of elevated levels of total cholesterol (TC) and low density lipoprotein cholesterol (LDL-C) has been a matter of concern in public health 8. It has been suggested that green tea drinking, a common practice in Japan and some other Asian countries, may lower serum TC and LDL-C. Green tea catechins have been shown to have a hypocholesterolemic effect in rats fed cholesterol-raising diets 6-8. Two cross-sectional studies recently reported that green tea consumption was associated with lower concentrations of serum TC and LDL-C in Japanese men 7,8. The present study further examined the relation of green tea consumption to serum lipids and lipoproteins in middle-aged Japanese men.

SUBJECTS AND METHODS

Study subjects were 2,062 male self-defense officials aged 49-55 years who received a preretirement health examination at the Self-Defense Forces Fukuoka and Kumamoto Hospitals from January 1991 to December 1992 and at the Sapporo Hospital from April to December in 1992. The preretirement health examination is part of the nationwide program for those retiring from the Self-Defense Forces. Details of the health examination has been described elsewhere 9,10. In the consecutive series of 2,228 men, 166 men were excluded in the present study due to the following conditions: hyperlipidemia under medication, diabetes mellitus under dietary or drug treatment, hyperthyroidism or hypothyroidism, steroid therapy, nephrotic syndrome or nephritis, coronary heart disease with drug thera-

Received April 10, 1996; accepted June 14, 1996.

1Department of Public Health, School of Medicine, Kyushu University, Fukuoka, Japan.
2Department of Public Health, National Defense Medical College, Tokorozawa, Japan.
3Self-Defense Forces Fukuoka Hospital, Kasuga, Japan.
4Self-Defense Forces Kumamoto Hospital, Kumamoto, Japan.
5Self-Defense Forces Sapporo Hospital, Sapporo, Japan.
Address for correspondence: Suminori Kono, Department of Public Health, School of Medicine, Kyushu University, Fukuoka, 812-82 Japan.
py, newly diagnosed cancer, and prior history of cancer, stroke, myocardial infarction or coronary angioplasty.

Venous blood was drawn after an overnight fast for the determination of serum biochemicals. Serum lipid measurements were performed at each hospital using reagents from different sources. Serum TC and triglycerides (TG) were determined by enzymatic methods using autoanalyzers. High density lipoprotein cholesterol (HDL-C) was enzymatically assayed using different precipitation methods (the heparin-Ca-Ni method or the dextran-Mg method). LDL-C concentrations were calculated according to the formula of Friedewald et al. Men having serum TG of 400 mg/dl or greater were not used in this calculation, and one man having an extraordinarily high concentration of TG (1049 mg/dl) was excluded in the analysis regarding TG. Coefficients of variation by hospital percentage (shochu, sake, beer, whiskey/brandy, and wine) on average. Alcohol intake was estimated from reported frequencies and amounts consumed per occasion of five different types of beverages (shochu, sake, beer, whiskey/brandy, and wine) on average. Alcohol intake was estimated from reported frequencies and amounts consumed per occasion of five different types of beverages (shochu, sake, beer, whiskey/brandy, and wine) on average. Consumption of the three items of fish dishes were combined into total fish consumption by adding frequencies per week. Total coffee consumption was obtained by adding weekly numbers of cups of brewed and instant coffee. Alcohol intake was estimated from reported frequencies and amounts consumed per occasion of five different types of beverages (shochu, sake, beer, whiskey/brandy, and wine) on average. Alcohol intake was estimated from reported frequencies and amounts consumed per occasion of five different types of beverages (shochu, sake, beer, whiskey/brandy, and wine) on average. Among several indices of physical activity, the weekly frequency of exercise was used as a measure of physical activity because it was most strongly correlated with serum HDL-C.

A priori selected as potential confounding variables were BMI, WHR, smoking habit, alcohol use, exercise, rank of the Self-Defense Forces, and hospital. BMI and WHR were always treated as continuous variables. Smoking habit was classified into four categories (never, past, and current smokers consuming <25 or 25+ cigarettes per day); alcohol use into five levels: never, past, and current drinkers consuming <30, 30-59 or 60 + ml of alcohol per day); exercise into three (0, 1–3 and 4+ times per week); and rank into three (low, middle, and high). Indicator terms were used for these categorical variables as well as for hospital. The age at examination was distributed in a narrow range, and 98% were those at the age of 51–53 years. Thus age was not taken into account. Dietary variables other than green tea were selected a posteriori for additional adjustment by using stepwise regression analysis.

Since the distribution of serum TG was skewed to the right side, natural logarithms of the values were used. Adjusted mean concentrations of serum lipids and lipoproteins according to green tea consumption were calculated by analysis of covariance, and trend of the association was assessed by multiple linear regression analysis assigning ordinal values to consumption levels of green tea. P values less than 0.05 (two-sided) were regarded as statistically significant. All computations were performed by the Statistical Analysis System (SAS) version 6.07J at Kyushu University Computer Center.

RESULTS

Daily users of green tea accounted for 88% of the study subjects, and the average number of cups consumed were 3.3 per day. There was no marked difference in BMI, WHR, smoking, alcohol use, and rank according to green tea consumption (Table 1). Men with higher consumption of green tea participated in physical exercises more frequently.

Table 2 summarizes serum concentrations of lipids and lipoproteins according to green tea consumption after adjustment for the predetermined confounding variables. Serum TC and LDL-C levels were almost progressively lower with increasing levels of green tea consumption. Green tea drinking was unrelated to serum HDL-C and TG. In the multiple linear regression analysis using a continuous, rather than categorical, variable for green tea, drinking 10 cups per day was associated with lower levels of TC by 7.3 mg/dl (95% confidence interval [CI] 1.5–13.1) and of LDL-C by 7.0 mg/dl (95% CI 1.5–12.5).

As shown in Table 3, green tea drinking was positively correlated with the consumption of foods typical of the traditional Japanese diets (rice, soy paste soup, and pickles), and negatively correlated with eating bread for breakfast and coffee consumption. Of the eight dietary variables which were significantly correlated with green tea consumption, rice (t = —3.44, p = 0.0006) and soy paste soup (t = —2.70, p = 0.007) each were related inversely to serum TC in multiple regression analysis using a continuous, rather than categorical, variable for green tea consumption. Serum TC and LDL-C levels were almost progressively lower with increasing levels of green tea consumption. Green tea drinking was unrelated to serum HDL-C and TG. In the multiple linear regression analysis using a continuous, rather than categorical, variable for green tea, drinking 10 cups per day was associated with lower levels of TC by 7.3 mg/dl (95% confidence interval [CI] 1.5–13.1) and of LDL-C by 7.0 mg/dl (95% CI 1.5–12.5).

As shown in Table 3, green tea drinking was positively correlated with the consumption of foods typical of the traditional Japanese diets (rice, soy paste soup, and pickles), and negatively correlated with eating bread for breakfast and coffee consumption. Of the eight dietary variables which were significantly correlated with green tea consumption, rice (t = —3.44, p = 0.0006) and soy paste soup (t = —2.70, p = 0.007) each were related inversely to serum TC in multiple regression analysis using a continuous, rather than categorical, variable for green tea, drinking 10 cups per day was associated with lower levels of TC by 7.3 mg/dl (95% confidence interval [CI] 1.5–13.1) and of LDL-C by 7.0 mg/dl (95% CI 1.5–12.5).

As shown in Table 3, green tea drinking was positively correlated with the consumption of foods typical of the traditional Japanese diets (rice, soy paste soup, and pickles), and negatively correlated with eating bread for breakfast and coffee consumption. Of the eight dietary variables which were significantly correlated with green tea consumption, rice (t = —3.44, p = 0.0006) and soy paste soup (t = —2.70, p = 0.007) each were related inversely to serum TC in multiple regression analysis using a continuous, rather than categorical, variable for green tea, drinking 10 cups per day was associated with lower levels of TC by 7.3 mg/dl (95% confidence interval [CI] 1.5–13.1) and of LDL-C by 7.0 mg/dl (95% CI 1.5–12.5).
Table 1. Behavioral and other characteristics according to green tea consumption in 2,062 male self-defense officials in Japan, 1991–1992

| Variable                  | Cups per day | P-value* |
|---------------------------|--------------|----------|
|                           | 0            | 1–3      | 4–6      | 7–9      | 10+      |     |
| No. of men                | 242          | 1,027    | 651      | 58       | 84       |     |
| Body mass index, mean (SE)| 23.96(0.16)  | 23.82(0.08)| 23.65(0.10)| 23.38(0.35)| 24.06(0.29)| 0.24|
| Waist-hip ratio, mean (SE)| 0.902(0.003) | 0.903(0.002)| 0.900(0.002)| 0.902(0.007)| 0.905(0.005)| 0.78|
| Current smoking (%)       | 48.3         | 52.8     | 49.5     | 44.8     | 51.2     | 0.48|
| Daily alcohol use (%)     | 43.8         | 44.3     | 46.4     | 41.4     | 35.7     | 0.43|
| Exercise, 4+ times/week (%)| 22.3        | 28.4     | 29.2     | 31.0     | 39.3     | 0.046|
| High rank (%)             | 7.9          | 11.8     | 12.1     | 6.9      | 10.7     | 0.32|

* Based on one-way analysis of variance or chi-square test.

Table 2. Adjusted mean (SE) concentrations (mg/dl) of serum lipids and lipoproteins according to green tea consumption in 2,062 male self-defense officials in Japan, 1991–1992

| Serum lipid and lipoprotein | Cups per day | Trend P |
|-----------------------------|--------------|---------|
|                             | 0            | 1–3     | 4–6     | 7–9     | 10+     |     |
| Total cholesterol*          | 203(2.1)     | 202(1.0) | 199(1.3)| 198(4.3)| 196(3.6)| 0.02|
| LDL cholesterol*            | 122(2.0)     | 121(1.0)| 118(1.2)| 114(4.0)| 116(3.4)| 0.02|
| HDL cholesterol*            | 55(0.8)      | 55(0.4)| 55(0.5)| 59(1.7)| 53(1.4)| 0.97|
| ln Triglycerides*           | 4.79(0.031)  | 4.76(0.015)| 4.76(0.019)| 4.71(0.063)| 4.78(0.053)| 0.56|

* Adjusted for body mass index, waist-hip ratio, smoking, alcohol use, exercise, rank, and hospital by analysis of covariance.

DISCUSSION

The present study corroborated an inverse relation between green tea drinking and serum TC and LDL-C reported previously in Japanese men. Imai and Nakachi also found higher levels of serum HDL-C and lower levels of serum TG among men with higher consumption of green tea. Like an earlier study of self-defense officials in northern Kyushu, Japan, the present study observed no such associations. We cannot provide plausible explanation for this discrepancy. Physical activity was not allowed for in their study, but our reported findings on HDL-C and TG were almost the same relation to these three dietary variables and coffee. Always included in the models as independent variables were BMI, WHR, smoking, alcohol use, exercise, rank, hospital, and green tea; a single continuous variable was used for each of the dietary factors. Only rice consumption was a significant, independent correlate of serum TC (t = -3.15, p = 0.002) and LDL-C (t = -2.30, p = 0.02). After additional adjustment for rice consumption (bowls per day), 10 cups of green tea per day was associated with lower levels of TC by 6.2 mg/dl (95% CI 0.4–12.1) and of LDL-C by 6.2 mg/dl (95% CI 0.7–11.7).
Table 3. Spearman’s rank correlation coefficients of green tea with other dietary variables in 2,062 male self-defense officials in Japan, 1991–1992

| Dietary variable                  | Spearman’s r | P-value |
|----------------------------------|--------------|---------|
| Rice (bowls per day)             | 0.10         | 0.0001  |
| Soy paste soup (bowls per week)  | 0.10         | 0.0001  |
| Pickles (times per week)         | 0.14         | 0.0001  |
| Bread for breakfast (times per week) | –0.09      | 0.0001  |
| Cheese (times per week)          | 0.00         | 0.96    |
| Raw vegetables (times per week)  | 0.09         | 0.0001  |
| Fruits (times per week)          | 0.09         | 0.0001  |
| Fish (times per week)            | 0.07         | 0.0002  |
| Meat (times per week)            | –0.01        | 0.72    |
| Garlic (times per week)          | 0.04         | 0.06    |
| Milk (glasses per week)          | 0.01         | 0.64    |
| Coffee (cups per day)            | –0.17        | 0.0001  |

Whether or not physical activity was taken into account (data not shown). Rice consumption was the single, significant dietary covariate for both TC and LDL-C, showing an inverse relationship. Rice consumption is probably a surrogate measure of the adherence to the Japanese diets or the practice of less Westernized diets. Coffee consumption was most strongly correlated inversely with green tea consumption. Although coffee did not emerge as a significant covariate in the stepwise regression, coffee consumption may have confounded the association of green tea with TC and LDL-C. In fact, some, not all, observational studies have reported a positive association between filtered or instant coffee and TC. Further adjustment for coffee did not change the relation between green tea and TC, but slightly weakened the association with LDL-C. Inverse associations of green tea with TC and LDL-C remained almost unchanged after allowance for rice and coffee consumption, conservative interpretation is needed. Dietary intakes of saturated fat, polyunsaturated fat, and cholesterol are considered to be important determinants of serum TC and LDL-C. The amount or frequency of consumption of limited food items is not sufficient to estimate intakes of these nutrients. Thus we could not examine potential confounding effects of these types of fat. Nonetheless the present findings add to epidemiological evidence in support of a possible cholesterol-lowering effect of green tea.

Among possible underlying mechanisms that have been proposed is the cholesterol-lowering effect of green tea catechins. Tea catechins were shown to reduce solubility of cholesterol in mixed micelles and also to decrease lymphatic cholesterol absorption from the intestine in rats. Green tea extract may prevent the decline of lecithin-cholesterol acyltransferase induced by cholesterol-rich diets, and thereby enhancing hepatic metabolism of cholesterol.

The inverse association between green tea and TC or LDL-C was relatively weak. Yet the magnitude of the true association may be greater than observed because both cholesterol levels determined by a single measurement and the self-reported amount of green tea are subject to random error. It would be of relevance to consider implication of a possible cholesterol-lowering effect of green tea in the prevention of coronary heart disease. In Western countries, a 1% reduction in an individual’s serum total cholesterol is related to a 2–3% reduction in the risk of coronary heart disease. A similar dose-response relation seems to exist in population with much lower levels of serum TC as suggested in a prospective study in China. If drinking 10 cups of green tea per day is associated with a 3% decrease in serum TC, then this amount of green tea would
confer a nearly 10% reduction in coronary heart disease risk individually.

Several cross-sectional studies have addressed the relation between black tea and serum TC and LDL-C. A study in Norway reported a significant inverse relation between tea consumption and serum TC; an inverse relation remained after additional adjustment for the frequency of use of specific food items. Another study in Israel found a non-significant, inverse association between tea and serum TC and LDL-C, allowing for coffee, sugar added, and non-dietary covariates. However, cross-sectional studies in the United States, Scotland, Finland, and Israel observed no association between tea consumption and either serum TC or LDL-C. Two of these studies made an adjustment for intakes of saturated fat and sugar. A study of Japanese men in Hawaii also found no association between tea drinking and serum TC, but types of tea under study were not specified in this study. An overview of these epidemiological data suggests that black tea drinking is not or very weakly, if any, related to serum TC or LDL-C. In black tea, most of the catechins are oxidized to thearubigins and theaflavins in the process of fermentation. Drinking green tea specifically, rather than tea in general, seems to be more relevant to the lower levels of serum TC and LDL-C.

ACKNOWLEDGEMENTS

The authors are grateful to the ward nurses of the Self-Defense Forces Fukuoka, Kumamoto, and Sapporo Hospitals for their cooperation; and Ms Satoko Kiyono and Mami Mochida at National Defense Medical College for their support in data management.

REFERENCES

1. Martin MJ, Browner WS, Hulley SB, Kuller LH, Wentworth D. Serum cholesterol, blood pressure and mortality: implications from a cohort of 361,662 men. Lancet, 1986; 2: 933 - 936.
2. Ministry of Health and Welfare of Japan. Report of the Fourth National Survey of Circulatory Disorders, 1990. Suita, Osaka: Japan Cardiovascular Research Foundation, 1993.
3. Consensus Conference. Lowering blood cholesterol to prevent heart disease. JAMA, 1985; 253: 2080-2086.
4. Muramatsu K, Fukuyo M, Hara Y. Effect of green tea catechins on plasma cholesterol level in cholesterol-fed rats. J Nutr Sci Vitaminol, 1986; 32: 613 - 622.
5. Chisaka T, Matsuda H, Kubomura Y, Mochizuki M, Yamahara J, Fujimura H. The effect of crude drugs on experimental hypercholesteremia: mode of action of (--) epigallocatechin gallate in tea leaves. Chem Pharm Bull, 1988; 36: 227 - 233.
6. Yamaguchi Y, Hayashi M, Yamazoe H, Kunitomo M. Preventive effects of green tea extract on lipid abnormalities in serum, liver and aorta of mice fed an atherogenic diet. Nippon Yakurigaku Zasshi, 1991; 97: 329 - 337.
7. Kono S, Shintchi K, Ikeda N, Yanai F, Imanishi K. Green tea consumption and serum lipid profiles: a cross-sectional study in northern Kyushu, Japan. Prev Med, 1992; 21: 526 - 531.
8. Imai K, Nakachi K. Cross sectional study of effects of drinking green tea on cardiovascular and liver diseases. BMJ, 1995; 310: 693 - 696.
9. Shintchi K, Kono S, Honjo S, et al. Obesity and adenomatous polyps of the sigmoid colon. Jpn J Cancer Res, 1994; 85: 479 - 484.
10. Kono S, Shintchi K, Todoroki I, et al. Gallstone disease among Japanese men in relation to obesity, glucose intolerance, exercise, alcohol use, and smoking. Scand J Gastroenterol, 1995; 30: 372 - 376.
11. Allain CC, Poon LS, Chan CS, Richmond W, Fu PC. Enzymatic determination of total serum cholesterol. Clin Chem, 1974; 20: 470 - 475.
12. Bucolo G, David H. Quantitative determination of serum triglycerides. Clin Chem, 1973; 19: 476 - 482.
13. Noma A, Nezu-Nakayama K, Kita M, Okabe H. Simultaneous determination of serum cholesterol and high- and low-density lipoproteins with use of heparin, Ca++, and an anion-exchange resin. Clin Chem, 1978; 24: 1504 - 1508.
14. Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. Clin Chem, 1972; 18: 499 - 502.
15. Bak AAA. Coffee and cardiovascular risk; an epidemiological study (thesis). Rotterdam: Erasmus University, 1990: 27 - 76.
16. Connor SL, Gustafson JR, Artaud-Wild SM, et al. The cholesterol/saturated-fat index: an indication of the hypercholesterolaemic and atherogenic potential of food. Lancet, 1986; 1: 1229 - 1232.
17. Zhou B, Rao X, Dennis BH, et al. The relationship between dietary factors and serum lipids in Chinese urban and rural populations of Beijing and Guangzhou. Int J Epidemiol, 1995; 24: 528 - 534.
18. Ikeda I, Imasato Y, Sasaki E, et al. Tea catechins decrease micellar solubility and intestinal absorption of cholesterol in rats. Biochim Biophys Acta, 1992; 1127: 141 - 146.
19. Law MR, Wald NJ, Thompson SG. By how much and how quickly does reduction in serum cholesterol concentration lower risk of ischaemic heart disease? BMJ, 1994; 308: 367 - 373.
20. Chen Z, Peto R, Collins R, MacMahon S, Lu J, Li W. Serum cholesterol concentration and coronary heart disease in population with low cholesterol concentrations. BMJ, 1991; 303: 276 - 282.
21. Stensvold I, Tverdal A, Soltvoll K, Foss OP. Tea consumption. Relationship to cholesterol, blood pressure, and coronary and total mortality. Prev Med, 1992; 21: 546 - 553.
22. Green MS, Harari G. Association of serum lipoproteins and health-related habits with coffee and tea consumption in free-living subjects examined in the Israeli CORDIS Study. Prev Med, 1992; 21: 532 - 545.
23. Davis BR, Curb JD, Borhani NO, Prineas RJ, Molteni A, for the Hypertension Detection and Follow-up Program Cooperative Group. Coffee consumption and serum cholesterol in the Hypertension Detection and Follow-up Program. Am J Epidemiol, 1988; 128: 124 - 136.
24. Klatsky AL, Petitti DB, Armstrong MA, Friedman GD. Coffee, tea and cholesterol. Am J Cardiol, 1985; 55: 577 - 578.
25. Carson CA, Cauley JA, Caggiula AW. Relation of caffeine intake to blood lipids in elderly women. Am J Epidemiol, 1993; 138: 94 - 100.
26. Brown CA, Bolton-Smith C, Woodward M, Tunstall-Pedoe H. Coffee and tea consumption and the prevalence of coronary heart disease in men and women: results from the Scottish Heart Health Study. J Epidemiol Community Health, 1993; 47: 171 - 175.
27. Tuomilehto J, Tanskanen A, Pietinen P, et al. Coffee consumption is correlated with serum cholesterol in middle-aged Finnish men and women. J Epidemiol Community Health, 1987; 41: 237 - 242.
28. Kark JD, Friedlander Y, Kaufmann NA, Stein Y. Coffee, tea, and plasma cholesterol: the Jerusalem Lipid Research Clinic prevalence study. Br Med J, 1985; 291: 699 - 704.
29. Curb JD, Reed DM, Kautz JA, Yano K. Coffee, caffeine, and serum cholesterol in Japanese men in Hawaii. Am J Epidemiol, 1986; 123: 648 - 655.
30. International Agency for Research on Cancer. Coffee, tea, mate, methylxanthines and methylglyoxal. IARC Monogr Eval Carcinogenic Risks Hum, 1991; 51: 217 - 233.