Green tea consumption and the risk of incident functional disability in elderly Japanese: the Ohsaki Cohort 2006 Study1–3

Yasutake Tomata, Masako Kakizaki, Naoki Nakaya, Toru Tsuboya, Toshimasa Sone, Shinichi Kuriyama, Atsushi Hozawa, and Ichiro Tsuji

ABSTRACT

Background: Previous studies have reported that green tea consumption is associated with a lower risk of diseases that cause functional disability, such as stroke, cognitive impairment, and osteoporosis. Although it is expected that green tea consumption would lower the risk of incident functional disability, this has never been investigated directly.

Objective: The objective was to determine the association between green tea consumption and incident functional disability in elderly individuals.

Design: We conducted a prospective cohort study in 13,988 Japanese individuals aged ≥65 y. Information on daily green tea consumption and other lifestyle factors was collected via questionnaire in 2006. Data on functional disability were retrieved from the public Long-term Care Insurance database, in which subjects were followed up for 3 y. We used Cox proportional hazards regression analysis to investigate the association between green tea consumption and functional disability.

Results: The 3-y incidence of functional disability was 9.4% (1316 cases). The multiple-adjusted HR (95% CI) of incident functional disability was 0.90 (0.77, 1.06) among respondents who consumed 1–2 cups green tea/d, 0.75 (0.64, 0.88) for those who consumed 3–4 cups/d, and 0.67 (0.57, 0.79) for those who consumed ≥5 cups/d in comparison with those who consumed <1 cup/d (P-trend < 0.001).

Conclusion: Green tea consumption is significantly associated with a lower risk of incident functional disability, even after adjustment for possible confounding factors. Am J Clin Nutr 2012;95:732–9.

INTRODUCTION

Tea is the most frequently consumed beverage in the world. Three billion kilograms of tea are produced worldwide annually. Because of the high rates of tea consumption in the global population, even small effects on an individual could have a large impact on public health.

The health effects of green tea have been extensively investigated by prospective cohort studies. We have found that green tea consumption is significantly associated with a lower risk of mortality due to stroke (1) and pneumonia (2) and a lower risk of cognitive impairment (3), depression (4), and psychological distress (5). These results have been confirmed by other researchers (6–9). In addition, other epidemiologic studies have indicated that green tea consumption is associated with a lower risk of osteoporosis (10, 11), and randomized controlled trials have indicated that green tea is effective for cardiovascular risk factors (12, 13). Because all of the above conditions are major causes of functional disability (14–16), it is expected that green tea consumption would contribute to disability prevention. To our knowledge, however, no study has yet investigated the relation between green tea consumption and the incident risk of functional disability.

We therefore conducted the present analysis to test the hypothesis that green tea consumption is associated with a lower risk of developing functional disability.

SUBJECTS AND METHODS

Study cohort

The design of the Ohsaki Cohort 2006 Study has been described in detail elsewhere (17). In brief, the source population for the baseline survey comprised 31,694 men and women aged ≥65 y who were living in Ohsaki City, northeastern Japan, on 1 December 2006.

The baseline survey was conducted between 1 December and 15 December 2006. A questionnaire was distributed by the heads of individual administrative districts to individual households and then collected by mail. In this analysis, 23,091 persons who provided valid responses formed the study cohort (Figure 1). We excluded 6333 persons who did not provide written consent for review of their Long-term Care Insurance (LTCI) information, 1979 persons who had already been certified as having disability by the LTCI at the time of the baseline survey, 5 persons who had died or moved out of the district during the period of the baseline

1 From the Division of Epidemiology, Department of Public Health and Forensic Medicine, Tohoku University Graduate School of Medicine, Sendai, Japan (YT, MK, NN, TT, TS, SK, AH, and IT); the Department of Nutrition and Dietetics, Faculty of Family and Consumer Sciences, Kama- kura Women’s University, Kamakura, Japan (NN); and the Department of Public Health, Yamagata University Graduate School of Medical Science, Yamagata, Japan (AH).

2 Supported by Health Sciences Research grants (nos. H21-Choju-Ippan-001 and H22-Choju-Ippan-001) from the Ministry of Health, Labor, and Welfare of Japan.

3 Address reprint requests and correspondence to Y Tomata, Division of Epidemiology, Department of Public Health and Forensic Medicine, Tohoku University Graduate School of Medicine 2-1, Seiryo-machi, Aoba-ku, Sendai, Miyagi 980-8575, Japan. E-mail: y-tomata@med.tohoku.ac.jp.

Received July 12, 2011. Accepted for publication December 22, 2011. First published online January 25, 2012; doi: 10.3945/ajcn.111.023200.
The LTCI system in Japan

In this study, we defined incident functional disability as certification for LTCI in Japan, which uses a nationally uniform standard of functional disability. LTCI is mandatory social insurance to assist daily activities in the frail and the elderly (24–28). Everyone aged ≥40 pays premiums, and everyone aged ≥65 is eligible for formal caregiving services. When a person applies to the municipal governments for benefits, a care manager visits his or her home and assesses the degree of functional disability by using a questionnaire developed by the Ministry of Health, Labor, and Welfare. Then, the municipal governments calculate the standardized scores for physical and mental functions on the basis of the questionnaire and classify whether the applicant is eligible for LTCI benefits (certification). If a person is judged as eligible for benefits, the Municipal Certification Committee decides on 1 of 7 levels of support, ranging from Support Level 1, Support Level 2, and Care Level 1 to Care Level 5. In brief, LTCI certification levels are defined as follows: Support Level 1 is defined as “limited in instrumental activities of daily living but independent in basic activities of daily living (ADLs)”. Care Level 2 is defined as “requiring assistance in at least one basic ADL task,” and Care Level 5 is defined as “requiring care in all ADL tasks.” A community-based study has shown that levels of LTCI certification are well correlated with ability to perform ADLs, and with Mini Mental State Examination scores (29). A prospective study has also indicated that levels of LTCI certification are significantly associated with mortality risk (30). LTCI certification was used as a measure of incident functional disability in the elderly (31–33).

Follow-up and case ascertainment

Incident functional disability was set as our endpoint, which was defined as LTCI certification. The primary outcome was LTCI certification (Support Level 1 or higher), in which deaths without
| Green tea consumption | <1 cup/d | 1–2 cups/d | 3–4 cups/d | ≥5 cups/d | P value<sup>1</sup> |
|-----------------------|---------|-----------|-----------|----------|-----------------|
| n                     | 2318    | 3141      | 3978      | 4551     |                 |
| Male sex (%)          | 57.0    | 48.9      | 42.5      | 36.0     | <0.001          |
| Age (y)               | 73.7 ± 6.2<sup>2</sup> | 73.9 ± 6.1 | 73.9 ± 5.9 | 74.0 ± 5.8 | 0.152           |
| BMI (kg/m<sup>2</sup>) | 23.7 ± 3.8 | 23.6 ± 3.4 | 23.5 ± 3.2 | 23.6 ± 3.3 | 0.319           |
| Psychological distress (%)<sup>3</sup> | 6.8     | 4.6       | 4.4       | 4.1      | <0.001          |
| Educational level <16 y (%) | 35.1    | 31.1      | 26.4      | 28.0     | <0.001          |
| Past history of (%)   |         |           |           |          |                 |
| Stroke                | 4.1     | 3.4       | 2.4       | 2.0      | <0.001          |
| Myocardial infarction | 6.3     | 5.2       | 5.1       | 4.2      | 0.003           |
| Hypertension          | 43.3    | 44.3      | 44.0      | 43.0     | 0.662           |
| Dyslipidemia          | 6.6     | 8.8       | 9.4       | 8.6      | 0.002           |
| Diabetes              | 12.5    | 12.0      | 12.0      | 11.5     | 0.646           |
| Arthritis             | 14.1    | 15.1      | 16.0      | 17.3     | 0.003           |
| Osteoporosis          | 9.8     | 10.2      | 11.4      | 11.4     | 0.091           |
| Fracture              | 16.1    | 16.7      | 15.9      | 15.3     | 0.404           |
| Cancer                | 8.8     | 8.1       | 9.2       | 8.6      | 0.437           |
| Hepatic disease       | 7.3     | 6.0       | 4.5       | 4.6      | <0.001          |
| Gastric and duodenal ulcer | 16.7   | 15.2      | 15.7      | 15.1     | 0.323           |
| Body pain ≥moderate (%) | 31.1   | 28.6      | 28.9      | 26.7     | <0.001          |
| Been in bed for >1 wk (%) | 5.9   | 3.7       | 3.2       | 2.9      | <0.001          |
| Weight reduction of ≥2 kg compared with 1 y ago (%) | 14.0  | 13.5      | 12.2      | 12.0     | 0.001           |
| Current smoker (%)    | 18.4    | 14.1      | 11.4      | 11.4     | <0.001          |
| Current alcohol drinker (%) | 43.9 | 39.9      | 36.8      | 32.8     | <0.001          |
| Frequent cognitive activity (%)<sup>4</sup> | 34.2 | 40.2      | 45.1      | 44.8     | <0.001          |
| Social support (%)    |         |           |           |          |                 |
| To consult when you are in trouble | 85.5 | 89.3      | 91.5      | 92.7     | <0.001          |
| To consult when you are in poor physical condition | 91.3 | 93.9      | 94.1      | 95.1     | <0.001          |
| To help with your daily housework | 82.8 | 85.2      | 86.2      | 86.9     | <0.001          |
| To take you to a hospital | 90.3 | 92.8      | 93.2      | 93.7     | <0.001          |
| To take care of you   | 84.9    | 88.2      | 87.0      | 86.8     | <0.001          |
| Participation in community activities (%) |         |           |           |          |                 |
| Activities in neighborhood association | 41.4 | 49.1      | 51.0      | 50.8     | <0.001          |
| Sports or exercise    | 39.7    | 47.9      | 49.4      | 50.3     | <0.001          |
| Volunteering          | 28.4    | 32.4      | 33.7      | 34.0     | 0.001           |
| Social gathering      | 40.9    | 49.3      | 52.4      | 53.0     | <0.001          |
| Time spent walking ≥1 h/d (%) | 39.0 | 36.9      | 35.4      | 32.5     | <0.001          |
| Better motor function (%)<sup>5</sup> | 75.4 | 76.1      | 78.5      | 79.2     | <0.001          |
| Intake of (g/d)       |         |           |           |          |                 |
| Rice                  | 434 ± 220 | 429 ± 228 | 425 ± 197 | 421 ± 186 | 0.078           |
| Miso soup             | 19.7 ± 9.7 | 20.2 ± 10.3 | 20.4 ± 8.6 | 21.7 ± 74.3 | 0.233           |
| Meat                  | 21.2 ± 15.7 | 22.4 ± 16.7 | 23.0 ± 16.2 | 23.6 ± 16.4 | <0.001          |
| Fish                  | 57.0 ± 32.5 | 59.1 ± 31.5 | 62.2 ± 30.8 | 65.7 ± 31.2 | <0.001          |
| Green and yellow vegetables | 79.8 | 46.6      | 89.5 ± 47.5 | 96.2 ± 45.9 | 105.4 ± 47.5 | 0.001          |
| Potatoes              | 21.2 ± 16.4 | 23.1 ± 16.2 | 25.4 ± 16.1 | 28.3 ± 16.6 | <0.001          |
| Soy products          | 57.6 ± 29.9 | 62.7 ± 28.3 | 66.0 ± 26.5 | 68.8 ± 25.5 | <0.001          |
| Fruit                 | 113.6 ± 89.8 | 132.1 ± 92.0 | 145.8 ± 91.0 | 160.6 ± 92.0 | <0.001          |
| Sweets                | 14.6 ± 15.7 | 16.6 ± 15.9 | 18.2 ± 16.2 | 20.3 ± 17.3 | <0.001          |
| Black tea consumption of <1 cup/d (%) | 95.5 | 86.6      | 91.6      | 90.7     | <0.001          |
| Oolong tea consumption of <1 cup/d (%) | 95.0 | 89.2      | 93.2      | 92.1     | <0.001          |
| Coffee consumption of <1 cup/d (%) | 50.4 | 40.2      | 48.2      | 55.2     | <0.001          |
| Energy intake (kcal/d)<sup>6</sup> | 1355 ± 423 | 1402 ± 417 | 1445 ± 394 | 1495 ± 374 | <0.001          |
| Protein intake (g/d)  | 48.9 ± 14.8 | 51.3 ± 14.5 | 53.9 ± 13.8 | 56.8 ± 13.7 | <0.001          |

<sup>1</sup> Obtained by using chi-square test for variables of proportion and 1-factor ANOVA for continuous variables.

<sup>2</sup> Mean ± SD (all such values).

<sup>3</sup> Kessler 6-item psychological distress scale score ≥13.

<sup>4</sup> Cognitive activity score ≥23.

<sup>5</sup> Motor function score of the Kihon Checklist <3.

<sup>6</sup> Excluding alcohol.
GREEN TEA AND DISABILITY

TABLE 2
Relation between green tea consumption and incident functional disability

| Incident functional disability | <1 cup/d | 1–2 cups/d | 3–4 cups/d | ≥5 cups/d | P-trend | P-interaction |
|--------------------------------|---------|-----------|-----------|-----------|---------|--------------|
| All (n = 13,988)               | 2318    | 3141      | 3978      | 4551      |         |              |
| No. of participants            | 296 (12.8) | 343 (10.9) | 339 (8.5) | 338 (7.4) |         |              |
| Primary outcome events [no. (%)] | 0.00 (reference) | 0.79 (0.68, 0.93) | 0.60 (0.51, 0.70) | 0.51 (0.44, 0.60) | <0.001 |              |
| Model 1                        | 1.00 (reference) | 0.85 (0.74, 1.01) | 0.70 (0.60, 0.82) | 0.61 (0.52, 0.72) | <0.001 |              |
| Model 2                        | 1.00 (reference) | 0.88 (0.75, 1.03) | 0.72 (0.61, 0.85) | 0.63 (0.54, 0.75) | <0.001 |              |
| Model 3                        | 1.00 (reference) | 0.90 (0.77, 1.06) | 0.75 (0.64, 0.88) | 0.67 (0.57, 0.79) | <0.001 |              |
| Model 4                        | 1.00 (reference) | 0.88 (0.69, 1.13) | 0.86 (0.68, 1.10) | 0.67 (0.52, 0.88) | 0.005 | 0.384        |
| Men (n = 6186)                 | 1320    | 1536      | 1691      | 1639      |         |              |
| No. of participants            | 140 (10.6) | 138 (9.0) | 140 (8.3) | 108 (6.6) |         |              |
| Primary outcome events [no. (%)] | 1.00 (reference) | 0.80 (0.63, 1.01) | 0.71 (0.56, 0.89) | 0.55 (0.42, 0.70) | <0.001 |              |
| Model 1                        | 1.00 (reference) | 0.90 (0.71, 1.15) | 0.87 (0.68, 1.10) | 0.64 (0.50, 0.83) | <0.001 |              |
| Model 2                        | 1.00 (reference) | 0.90 (0.70, 1.14) | 0.85 (0.66, 1.08) | 0.64 (0.49, 0.83) | 0.001 |              |
| Model 3                        | 1.00 (reference) | 0.88 (0.69, 1.13) | 0.86 (0.68, 1.10) | 0.67 (0.52, 0.88) | 0.005 | 0.384        |
| Women (n = 7802)               | 998     | 1605      | 2287      | 2912      |         |              |
| No. of participants            | 156 (15.6) | 205 (12.8) | 199 (8.7) | 230 (7.9) |         |              |
| Primary outcome events [no. (%)] | 1.00 (reference) | 0.78 (0.64, 0.96) | 0.53 (0.43, 0.66) | 0.49 (0.40, 0.60) | <0.001 |              |
| Model 1                        | 1.00 (reference) | 0.83 (0.67, 1.02) | 0.61 (0.50, 0.76) | 0.58 (0.47, 0.71) | <0.001 |              |
| Model 2                        | 1.00 (reference) | 0.84 (0.68, 1.04) | 0.64 (0.52, 0.80) | 0.62 (0.50, 0.77) | <0.001 |              |
| Model 3                        | 1.00 (reference) | 0.87 (0.70, 1.07) | 0.67 (0.54, 0.83) | 0.65 (0.53, 0.81) | <0.001 |              |

1 Model 1 was adjusted for age (65–69, 70–74, 75–79, 80–84, or ≥85 y) and sex (among all participants). Model 2 was adjusted as for model 1 plus history of disease [stroke, myocardial infarction, hypertension, arthritis, osteoporosis, or fracture (yes, no)], educational level (age at last school graduation: <16 y, 16–18 y, ≥19 y, or missing), smoking (never, former, current, or missing), alcohol drinking (never, former, current, or missing), BMI (in kg/m²; <18.5, 18.5–24.9, ≥25.0, or missing), cognitive activity score (<19, 19–23, ≥23, or missing), psychological distress score (<13, ≥13, or missing), and time spent walking (<30 min/d, 30 min to 1 h/d, ≥1 h/d, or missing). Model 3 was adjusted as for model 2 plus 3 tertile groups of consumption volume of rice, miso soup, meat, fish, green and yellow vegetables, potatoes, soy products, fruit, and sweets. Model 4 was adjusted as for model 3 plus social support (whether subject perceived that he or she was supported for all 5 categories), participation in community activities (whether subject participated in any of 4 categories), and motor function score(<3, ≥3, or missing).  

2 HR; 95% CI in parentheses (all such values).

LTCI certification were treated as censored. In the subanalysis, we set the criteria of disability toward a more severe level, ie, Care Level 2 (requiring assistance with one basic ADL task) or higher.

We obtained information on the date of LTCI certification, death, or moving from Ohsaki City. With regard to LTCI certification, information on care level was also provided. All data were transferred from the Ohsaki City Government under the agreement related to Epidemiologic Research and Privacy Protection yearly each December.

Ethical issues

We considered the return of completed questionnaires to imply consent to participate in the study involving the baseline survey data and subsequent follow-up of death and emigration. We also confirmed information regarding LTCI certification status after obtaining written consent from the subjects. The Ethics Committee of Tohoku University Graduate School of Medicine (Sendai, Japan) reviewed and approved the study protocol.

Statistical analysis

We counted the person-years of follow-up for each subject from 16 December 2006 until the date of incident functional disability, date of moving from Ohsaki City, date of death, or the end of the study period (30 November 2009), whichever occurred first.

Baseline characteristics were evaluated by using ANOVA for continuous variables and the chi-square test for categorical variables. We used the multiple adjusted Cox proportional hazards model to calculate HRs and 95% CIs for incidence of functional disability according to amounts of green tea consumption.

We defined respondents who consumed <1 cup green tea/d as the reference category, and examined the relation between green tea consumption and incident functional disability by using the following models. Model 1 was sex- and age-adjusted. To examine whether the association between green tea consumption and incident functional disability could be explained as resulting from healthy physical status or other lifestyle factors, model 2 was further adjusted for history of stroke, myocardial infarction, hypertension (individuals with self-measured systolic blood pressure ≥140 mm Hg or diastolic blood pressure ≥90 mm Hg were also defined as hypertensive), arthritis, osteoporosis and fracture, educational level, smoking status, alcohol consumption, BMI, tertile categories of cognitive activity score, psychological distress score, and time spent walking per day. Because green tea consumption was thought to be especially related to a healthy dietary pattern, model 3 was further adjusted for 3 tertile groups of consumption volume of rice, miso soup, meat, fish, green and yellow vegetables, potatoes, soy products, fruit, and sweets. Model 4 was fully adjusted and included answers to questions about social support, participation in community activities, and motor function score.
Social support

Participation in community activities

participants who participated in at least one community activity.

participants who perceived that they were supported for all 5 social support categories; Participated,

participate in any community activities; No lack, participants who perceived that they were supported for all 5 social support categories; Participated,

In the analyses for black tea, oolong tea, or coffee as a main

coffee as independent variables by using the fully adjusted model

For analysis of social support and participation in community

activity (5, 34). Therefore, we further stratified the responses

according to social support and community activity. Those who did

not answer any questions about social support or participation in

community activities were excluded from these stratified analyses.

For analysis of social support and participation in community

activities, neither of these was used as the respective covariate.

We also analyzed the consumption of black tea, oolong tea, and

coffee as independent variables by using the fully adjusted model

(model 4). In the analyses for black tea, oolong tea, or coffee as a main

exposure, persons with missing data were excluded (n = 11,449 for

black tea, n = 12,883 for oolong tea, and n = 11,362 for coffee).

All data were analyzed by using SAS version 9.1 (SAS Institute

Inc). All statistical tests described here were 2-sided, and differences at \( P < 0.05 \) were accepted as significant.

RESULTS

The baseline characteristics of the participants according to

green tea consumption category are shown in Table 1. Subjects

who consumed larger amounts of green tea were less likely to be

men, to suffer from psychological distress, to have <16 y of

education, to have shown a weight reduction of >2 kg compared

with 1 y ago, to be current smokers, to be current alcohol drinkers,

and to have a history of stroke, myocardial infarction, or hepatic

disease. More frequent consumption of green tea was associ-

ated with significantly higher consumption of meat, fish, green

and yellow vegetables, soy products, fruits, and sweets; greater

intake of energy and protein; better cognitive activity; better per-

ception of support for all 5 social support categories; and greater

participation in the 4 community activities categories. Conversely,

subjects who more frequently consumed green tea included a higher

proportion of individuals with arthritis and a lower proportion of

individuals who walked ≥1 h/d.

The relation between green tea consumption and incident functional disability with HRs and associated 95% CIs are shown in

Table 2. We found that green tea consumption was inversely as-

associated with incident functional disability in model 1 (P-trend < 0.001). Even with the addition of the several adjustment items, these associations remained significant. In model 4, the multivari-

te HRs were 1.00 (reference) for <1 cup/d, 0.90 (95% CI: 0.77, 1.06) for 1–2 cups/d, 0.75 (95% CI: 0.64, 0.88) for 3–4 cups/d, and

0.67 (95% CI: 0.57, 0.79) for ≥5 cups/d. This inverse association was significant for both sexes (\( P = 0.384 \) for interaction with sex).

Even if we set stricter criteria for disability (LTCI certification for Care Level 2 or higher), the results did not change. The multivariate

HRs (model 4) were 1.00 (reference) for <1 cup/d, 0.92 (95% CI: 0.72, 1.17) for 1–2 cups/d, 0.71 (95% CI: 0.55, 0.91) for 3–4 cups/d, and

0.68 (95% CI: 0.53, 0.88) for ≥5 cups/d (data not shown).

To examine possible reverse causality, we analyzed whether the association would be different by excluding participants

whose event of disability occurred in the first year of follow-up. When we excluded 577 such participants, the results did not

change substantially. The multivariate HRs (model 4) were 1.00 (reference) for <1 cup/d, 0.91 (95% CI: 0.75, 1.10) for 1–2 cups/d,

0.81 (95% CI: 0.66, 0.98) for 3–4 cups/d, and 0.71 (95% CI: 0.58, 0.87) for ≥5 cups/d (data not shown). In addition, when we ex-

cluded participants with any history of diseases that cause func-

tional disability (stroke, myocardial infarction, hypertension, arthritis, osteoporosis, or fracture), the results also did not change.

| Social support | <1 cup/d | 1–2 cups/d | 3–4 cups/d | ≥5 cups/d | P-trend | P-interaction |
|----------------|----------|------------|------------|-----------|---------|---------------|
| No lack        |          |            |            |           |         |               |
| No. of participants | 1570     | 2252       | 2947       | 3392      |         |               |
| Primary outcome events [no. (%)] | 208 (13.3) | 248 (11.0) | 235 (8.0) | 239 (7.1) |         |               |
| Age and sex-adjusted HR (95% CI)² | 1.00 (reference) | 0.75 (0.63, 0.90) | 0.54 (0.45, 0.65) | 0.46 (0.38, 0.56) | <0.001 |               |
| Multiple-adjusted HR (95% CI)³ | 1.00 (reference) | 0.89 (0.73, 1.07) | 0.66 (0.56, 0.83) | 0.61 (0.50, 0.75) | <0.001 | 0.103         |
| Any lack       |          |            |            |           |         |               |
| No. of participants | 624      | 710        | 867        | 979       |         |               |
| Primary outcome events [no. (%)] | 74 (11.9) | 75 (10.6)  | 81 (9.3)   | 83 (8.5)  |         |               |
| Age and sex-adjusted HR (95% CI)² | 1.00 (reference) | 0.86 (0.62, 1.19) | 0.65 (0.48, 0.90) | 0.59 (0.43, 0.81) | <0.001 |               |
| Multiple-adjusted HR (95% CI)³ | 1.00 (reference) | 0.95 (0.68, 1.33) | 0.78 (0.56, 1.09) | 0.74 (0.53, 1.04) | 0.047  |               |

| Participation in community activities |          |            |            |           |         |               |
|--------------------------------------|----------|------------|------------|-----------|---------|---------------|
| Did not participate                  |          |            |            |           |         |               |
| No. of participants                  | 781      | 802        | 951        | 1066      |         |               |
| Primary outcome events [no. (%)]     | 162 (20.7)| 164 (20.5) | 139 (14.6) | 142 (13.3)|         |               |
| Age and sex-adjusted HR (95% CI)²    | 1.00 (reference) | 0.86 (0.69, 1.07) | 0.62 (0.49, 0.78) | 0.55 (0.44, 0.70) | <0.001 |               |
| Multiple-adjusted HR (95% CI)³       | 1.00 (reference) | 0.90 (0.72, 1.13) | 0.69 (0.55, 0.88) | 0.64 (0.50, 0.81) | <0.001 |               |

¹ Any lack, participants who perceived that they were not supported for at least one social support category; Did not participate, participants who did not participate in any community activities; No lack, participants who perceived that they were supported for all 5 social support categories; Participated, participants who participated in at least one community activity.

² Adjusted as for model 1 in Table 2.

³ Adjusted as for model 4 in Table 2.
DISCUSSION

In this study, we found significant inverse dose-response associations between green tea consumption and incident functional disability. To our knowledge, this is the first reported study to have proved the relation between green tea consumption and incident risk of functional disability.

Our study had a number of strengths: 1) it was a large population-based cohort study in 13,988 persons, 2) it had a follow-up rate of almost 100%, 3) the study subjects lived in an area in which green tea is widely consumed, and 4) many confounding factors were taken into account.

Because green tea consumption is associated with a variety of health behavior or social factors, we used several approaches to control for these effects. First, we adjusted the effect of dietary habit, because green tea is usually consumed with a Japanese-style diet such as fish and soy bean products (Table 1). Consumption of fish and soy products has been reported to reduce the risk of stroke, fracture, and dementia (35–40). However, our results indicated that the association between green tea consumption and incident functional disability did not alter, even when dietary covariates were adjusted for.

Second, we also considered the confounding effect of social support or community activities. Previous studies have shown that these factors are associated with a lower risk of functional disability (41, 42). However, we found that the inverse association between green tea consumption and incident functional disability persisted even after adjustment for social support and participation in community activities.

Because our follow-up period was only 3 y, the effects of reverse causality could not be fully avoided. However, the strong inverse relation between green tea consumption and incident functional disability persisted even after excluding individuals who experienced incident functional disability in the first year of follow-up. The above findings suggest that the present results are unlikely to be explained by reverse causality.

We thus considered that the inverse relation between green tea consumption and functional disability risk would be attributable to the preventive effect of green tea consumption on disabling diseases such as stroke, cognitive impairment, and osteoporosis. These diseases are major causes of functional disability in Japanese elderly individuals, with prevalence as follows: 23.3% for stroke, 14.0% for dementia, 12.2% for articular disease, and 9.3% for bone fracture (43). As we noted before, green tea consumption was associated with lower risks of stroke, dementia, and bone fracture. This survey reported that the third most common cause of functional disability was “frailty” (13.6%), which is mostly associated with sarcopenia and lower muscle strength. More recently, green tea polyphenols have been reported to improve leg strength (44). Furthermore, depression is also known to pose a risk of functional disability (45). Our previous study indicated that green tea consumption was associated with a lower risk of depression. All of these findings provide a biological basis for the effect of green tea in preventing or postponing the onset of functional disability in the elderly.

In contrast to green tea, we observed no association between black tea, oolong tea, or coffee consumption and incident functional disability.

| TABLE 4 | Relation between consumption of other beverages and incident functional disability |
|----------------|-------------------------------|----------------|----------------|----------------|
| Beverage consumption | <1 cup/d | 1–2 cups/d | 3–4 cups/d | ≥5 cups/d |
| Oolong tea (Chinese tea) | 10,482 | 502 | 225 | 153 |
| Primary outcome events [no. (%)] | 925 (8.8) | 45 (9.0) | 11 (4.9) | 13 (8.5) |
| Age- and sex-adjusted HR (95% CI) | 1.00 (reference) | 1.12 (0.83, 1.52) | 0.58 (0.32, 1.05) | 0.94 (0.54, 1.63) |
| Multiple-adjusted HR (95% CI) | 1.00 (reference) | 1.47 (1.07, 2.03) | 0.77 (0.42, 1.40) | 1.25 (0.71, 2.18) |
| Black tea | 10,408 | 785 | 190 | 66 |
| Primary outcome events [no. (%)] | 914 (8.8) | 73 (9.3) | 11 (5.8) | 4 (6.1) |
| Age- and sex-adjusted HR (95% CI) | 1.00 (reference) | 1.11 (0.87, 1.41) | 0.61 (0.34, 1.11) | 0.65 (0.24, 1.74) |
| Multiple-adjusted HR (95% CI) | 1.00 (reference) | 1.23 (0.96, 1.59) | 0.82 (0.45, 1.51) | 1.01 (0.37, 2.75) |
| Coffee | 6317 | 4997 | 1031 | 538 |
| Primary outcome events [no. (%)] | 701 (11.1) | 357 (7.1) | 62 (6.0) | 41 (7.6) |
| Age- and sex-adjusted HR (95% CI) | 1.00 (reference) | 0.83 (0.73, 0.94) | 0.82 (0.63, 1.07) | 0.92 (0.67, 1.27) |
| Multiple-adjusted HR (95% CI) | 1.00 (reference) | 0.90 (0.79, 1.03) | 0.93 (0.72, 1.22) | 1.02 (0.74, 1.41) |

1 Adjusted as for model 1 in Table 2.
2 Adjusted as for model 4 in Table 2.
3 Adjusted as for model 4 in Table 2.
disability, which is consistent with previous epidemiologic studies (1, 3–5). This discrepancy among beverages suggests that the effect of green tea cannot be explained by fluid intake but rather by some component in the beverage. As compared with black tea and oolong tea, green tea contains a large amount of polyphenols such as epigallocatechin gallate, which reduce oxidative damage to DNA and lipid concentrations (46–48). Randomized controlled trials of green tea polyphenol have indicated that it exerts antiatherosclerotic effects by reducing the level of oxidative stress (49).

This study had several limitations. First, we did not investigate the causes of functional disability in subjects who received LTCI certification. Thus, the mechanism responsible for functional disability reduction by green tea remained unidentified.

Second, among the source population of 31,694, the valid response rate (72.9%, \( n = 23,091 \)) in the present study was not high. In addition, among the number of valid responses (\( n = 23,091 \)), the number of subjects included in the present study was 13,988 (60.6%) and the number of those who were not included was 9103 (39.4%). Three-year follow-up indicated that mortality was higher in the nonstudy subjects (13%) than in the study subjects (5%). Thus, the present study would have been biased toward the healthier people in the community. However, this bias did not explain to affect the internal validity of association between green tea consumption and incident functional disability.

Third, not all potential confounding factors were considered, because we used only indirect measures of physical and cognitive function for adjustment. Furthermore, addition of income to the multivariate analysis might have been an appropriate indicator of socioeconomic status.

Fourth, because not all candidates applied for LTCI certification, this study may not have been completely free from detection bias. The degree of this bias remains to be verified.

In conclusion, this cohort study indicates that green tea consumption is inversely associated with incident functional disability. Clinical trials are ultimately necessary to confirm the protective effect of green tea against functional disability.

We thank Yosihoko Nakata, Mika Wagatsuma, and Yoko Kikuchi for their technical assistance.

The authors’ responsibilities were as follows—YT, MK, SK, AH, and IT: study concept and design; YT, MK, NN, SK, AH, and IT: acquisition of data; YT, MK, TT, SK, AH, and IT: analysis and interpretation of data; YT: drafting of the manuscript; YT, MK, NN, TT, TS, SK, AH, and IT: critical revision of the manuscript for important intellectual content; YT, MK, AH, and IT: statistical analysis; and IT: study supervision. None of the authors declared a conflict of interest.

REFERENCES

1. Kuriyama S, Shimazu T, Ohmori K, Kikuchi N, Nakaya N, Nishino Y, Tsubono Y, Tsugi J. Green tea consumption and disability: a food-frequency questionnaire for cohort studies in rural Japan. JAMA 2006;296:1255–65.

2. Watanabe I, Kuriyama S, Kakizaki M, Sone T, Ohmori-Matsuda K, Nakaya N, Hozawa A, Tsugi J. Green tea and death from pneumonia in Japan: the Ohsaki cohort study. J Clin Nutr 2009;88:1390–6.

3. Hozawa A, Kuriyama S, Nakaya N, Ohmori-Matsuda K, Kakizaki M, Sone T, Nagai M, Sugawara Y, Nitta A, Tomata Y, et al. Green tea consumption is associated with lower psychological distress in a general population: the Ohsaki Cohort 2006 Study. Am J Clin Nutr 2009;89:1390–6.

4. Arab L, Liu W, Elashoff D. Green and black tea consumption and risk of stroke: a meta-analysis. Stroke 2009;40:1786–92.

5. Mineharu Y, Koizumi A, Wada Y, Iso H, Watanabe Y, Date C, Yamamoto A, Kikuchi S, Inaba Y, Toyoshima H, et al. Coffee, green tea, black tea and oolong tea consumption and risk of mortality from cardiovascular disease in Japanese men and women. J Epidemiol Community Health 2011;65:230–40.

6. Sone T, Nagai M, Sugawara Y, Nitta A, Tomata Y, et al. Green tea consumption is associated with lower psychological distress in a general population: the Ohsaki Cohort 2006 Study. Am J Clin Nutr 2009;89:1390–6.

7. Nantz MP, Rowe CA, Bukowski JF, Percival SS. Standardized capsule of Camellia sinensis lowers cardiovascular risk factors in a randomized, double-blind, placebo-controlled study. Nutrition 2009;25:147–54.

8. Hooper L, Kroon PA, Rimm EB, Liu W, Wu JS, Chang CJ. Epidemiological evidence of increased bone mineral density in habitual tea drinkers. Arch Intern Med 2002;162:1001–6.

9. Kuriyama S, Hozawa A, Shimazu T, Ogawa K, Tsuji I. Green tea consumption and incident long-term care insurance certification: the Tokamachi-Nakasato cohort study in Japan. Int J Epidemiol 2008;37:40–40.

10. Wu CH, Yang YC, Yao WJ, Lu FH, Wu JS, Chang CJ. Green tea consumption is associated with depressive symptoms in the elderly. Am J Clin Nutr 2006;83:355–61.

11. Mori S, Yamamoto S, Ishibashi H, Oka H, Yoshimura N, Kawaguchi H, Nakamura K. Diet and lifestyle associated with increased bone mineral density: cross-sectional study of Japanese elderly women at an osteoporosis outpatient clinic. J Orthop Sci 2007;12:317–20.

12. Nantz MP, Rowe CA, Bukowski JF, Percival SS. Standardized capsule of Camellia sinensis lowers cardiovascular risk factors in a randomized, double-blind, placebo-controlled study. Nutrition 2009;25:147–54.

13. Hooper L, Kroon PA, Rimm EB, Liu W, Wu JS, Chang CJ. Epidemiological evidence of increased bone mineral density in habitual tea drinkers. Arch Intern Med 2002;162:1001–6.

14. Sousa RM, Ferri CP, Acosta D, Albanese E, Guerra M, Huang Y, Jacob KS, Johnston CC, Rodriguez EJ, Pichard GR, et al. Contribution of chronic diseases to disability in elderly people in countries with low and middle incomes: a 10/66 Dementia Research Group population-based survey. Lancet 2009;374:1821–30.

15. Spier NA, Matthews RJ, Jagger C, Matthews HE, Boulc H, Robinson TG, Brayne C. Diseases and impairments as risk factors for onset of disability in the older population in England and Wales: findings from the Medical Research Council Cognitive Function and Ageing Study. J Gerontol A Biol Sci Med Sci 2005;60:248–54.

16. Wolff JL, Boulc H, Boyd C, Anderson G. Newly reported chronic conditions and onset of functional dependency. J Am Geriatr Soc 2005;53:851–5.

17. Kuriyama S, Nakaya N, Ohmori-Matsuda K, Shimazu T, Kikuchi N, Kakizaki M, Sone T, Sato F, Nagai M, Sugawara Y, et al. The Ohsaki cohort 2006 study: design of study and profile of participants at baseline. J Epidemiol 2010;20:253–8.

18. Wilson RS, Mendes De Leon CF, Barnes LL, Schneider JA, Biemans JL, Evans DA, Bennett DA. Participation in cognitively stimulating activities and risk of incident Alzheimer disease. JAMA 2002;287:742–8.

19. Nantz MP, Rowe CA, Bukowski JF, Percival SS. Standardized capsule of Camellia sinensis lowers cardiovascular risk factors in a randomized, double-blind, placebo-controlled study. Nutrition 2009;25:147–54.

20. Kessler RC, Barker DJP, Colpe LJ, Epstein JF, Gfroerer JC, Hiripi E, Hodges JM, Normand SL, Walters EE, et al. Screening for serious mental illness in the general population. Arch Gen Psychiatry 2002;59:1001–6.

21. Wilson RS, Mendes De Leon CF, Barnes LL, Schneider JA, Biemans JL, Evans DA, Bennett DA. Participation in cognitively stimulating activities and risk of incident Alzheimer disease. JAMA 2002;287:742–8.

22. Brayne C. Diseases and impairments as risk factors for onset of disability in elderly people in countries with low and middle incomes: a 10/66 Dementia Research Group population-based survey. Lancet 2009;374:1821–30.

23. Wilson RS, Mendes De Leon CF, Barnes LL, Schneider JA, Biemans JL, Evans DA, Bennett DA. Participation in cognitively stimulating activities and risk of incident Alzheimer disease. JAMA 2002;287:742–8.
24. Imai H, Fujii Y, Fukuda Y, Nakao H, Yahata Y. Health-related quality of life and beneficiaries of long-term care insurance in Japan. Health Policy 2008;85:349–55.
25. Ikegami N. Public long-term care insurance in Japan. JAMA 1997;278:1310–4.
26. Tsutsui T, Muramatsu N. Care-needs certification in the long-term care insurance system of Japan. J Am Geriatr Soc 2005;53:522–7.
27. Imahashi K, Kawagoe M, Eto F, Haga N. Clinical status and dependency of the elderly requiring long-term care in Japan. Tohoku J Exp Med 2007;212:229–38.
28. Ministry of Health, Labor, and Welfare. Long-term care insurance in Japan. Tokyo, Japan: Ministry of Health, Labor, and Welfare, 2008. Available from: http://www.mhlw.go.jp/english/topics/elderly/care/index.html (cited 20 October 2011).
29. Arai Y, Zarit SH, Kumamoto K, Takeda A. Are there inequities in the assessment of dementia under Japan’s LTC insurance system? Int J Geriatr Psychiatry 2003;18:346–52.
30. Takeda S. Two-year survival and changes in the level of care for the elderly patients recognized as in need of long-term care in the public nursing-care insurance scheme. Nippon Koshu Eisei Zasshi 2004;51:157–67 (in Japanese).
31. Kondo N, Kawachi I, Hirai H, Kondo K, Subramanian SV, Hanibuchi T, Yamagata Z. Relative deprivation and incident functional disability among older Japanese women and men: prospective cohort study. J Epidemiol Community Health 2009;63:461–7.
32. Nitta A, Hozawa A, Kuriyama S, Nakaya N, Ohmori-Matsuda K, Sone T, Kakizaki M, Ebihara S, Ichiki M, Arai H. Relationship between peripheral arterial disease and incident disability among elderly Japanese: the Tsurugaya project. J Atheroscler Thromb 2010;17(17):1290–6.
33. Hozawa A, Sugawara Y, Tomata Y, Kakizaki M, Ohmori-Matsuda K, Nakaya N, Kuriyama S, Fukao S, Tsuji I. Relationships between N-terminal pro B-type natriuretic peptide and incident disability and mortality in older community-dwelling adults: the Tsurugaya study. J Am Geriatr Soc 2010;58:2439–41.
34. Saito M, Kobayashi A, Hattori Y. The Effects of “OCHANOMI” on elderly individuals, aged 65 to 74, in relation to social support, subjective well-being, and results of social exchanges. J Jpn Acad Com Health Nurs 2005;7:41–7 (in Japanese).
35. Shimazu T, Kuriyama S, Hozawa A, Ohmori K, Sato Y, Nakaya N, Nishino Y, Tsabono Y, Tsuji I. Dietary patterns and cardiovascular disease mortality in Japan: a prospective cohort study. Int J Epidemiol 2007;36:600–9.
36. Hooper L, Thompson RL, Harrison RA, Summerbell CD, Moore H, Worthington HV, Durrington PN, Ness AR, Capps NE, Davey Smith G, et al. Omega 3 fatty acids for prevention and treatment of cardiovascular disease. Cochrane Database Syst Rev 2004;18:4(CD003177.
37. Lim WS, Gammack JK, Van Niekerk J, Dangour AD. Omega 3 fatty acid for the prevention of dementia. Cochrane Database Syst Rev 2006;25:1(CD005379.
38. Carlson S, Peng N, Prasain JK, Wyss JM. Effects of botanical dietary supplements on cardiovascular, cognitive, and metabolic function in males and females. Gend Med 2008;5(suppl A):S76–90.
39. Lee YB, Lee HJ, Sohn HS. Soy isoflavones and cognitive function. J Nutr Biochem 2005;16:641–9.
40. Atmaca A, Kleerekoper M, Bayraktar M, Kucuk O. Soy isoflavones in the management of postmenopausal osteoporosis. Menopause 2008;15(4):748–57.
41. Mendes de Leon CF, Gold DT, Glass TA, Kaplan L, George LK. Disability as a function of social networks and support in elderly African Americans and Whites: the Duke EPESE 1986-1992. J Gerontol B Psychol Sci Soc Sci 2001;56:S179–90.
42. Jung Y, Gruenewald TL, Seeman TE, Sarkisian CA. Productive activities and development of frailty in older adults. J Gerontol B Psychol Sci Soc Sci 2001;56:S179–90.
43. Ministry of Health, Labor, and Welfare. 19. Percentage distribution of major causes due to need of assistance or care by sex, 2007. Comprehensive Survey of Living Conditions. Available from: http://www.mhlw.go.jp/english/database/db-hss/cslc-tables.html (cited 20 October 2011).
44. Shen CL, Chyu MC, Yeh JK, Zhang Y, Pence BC, Felton CK, Brismée JM, Arjmandi BH, Doctolero S, Wang JS. Effect of green tea and Tai Chi on bone health in postmenopausal osteopenic women: a 6-month randomized placebo-controlled trial. Osteoporos Int (Epub ahead of print 16 July 2011).
45. Lenze EJ, Schulz R, Martire LM, Zdaniuk B, Glass T, Kop WJ, Jackson SA, Reynolds CF III. The course of functional decline in older people with persistently elevated depressive symptoms: longitudinal findings from the Cardiovascular Health Study. J Am Geriatr Soc 2005;53:569–75.
46. Cabrera C, Giménez R, López MC. Determination of tea components with antioxidant activity. J Agric Food Chem 2003;51:4427–35.
47. Han KC, Wong WC, Benzie IF. A genoprotective effects of green tea (Camellia sinensis) in human subjects: results of a controlled supplementation trial. Br J Nutr 2011;105:171–9.
48. Erba D, Riso P, Bordoni A, Foti P, Biagi PL, Testolin G. Effectiveness of moderate green tea consumption on antioxidative status and plasma lipid profile in humans. J Nutr Biochem 2005;16:144–9.
49. Oyama J, Maeda T, Kouzuma K, Ochiai R, Tokimitsu I, Higuchi Y, Sugano M, Makino N. Green tea catechins improve human forearm endothelial dysfunction and have antiatherosclerotic effects in smokers. Circ J 2010;74:578–88.