

Green tea consumption and the risk of incident functional disability in elderly Japanese: the Ohsaki Cohort 2006 Study^{1–3}

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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* doi: 10.3945/ajcn.111.023200.

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

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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.

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Received July 12, 2011. Accepted for publication December 22, 2011.
doi: 10.3945/ajcn.111.023200.

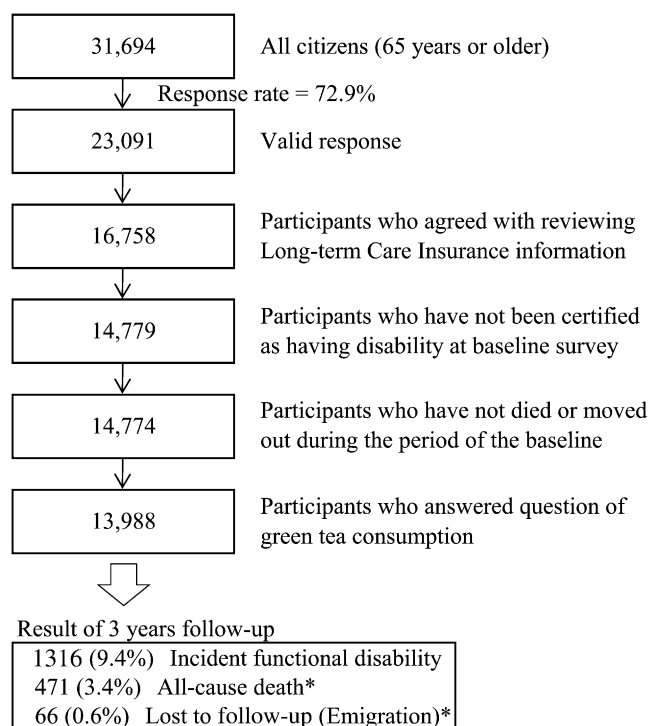


FIGURE 1. Flowchart of study participants: the Ohsaki Cohort 2006 Study. *Without experiencing incident functional disability.

survey, and 786 persons who missed answering the questions on green tea consumption. Thus, 13,988 responses were analyzed for the purposes of this study.

During the 3-y period, only 66 persons were lost to follow-up because of moving from the study area, without developing incident functional disability, which provided a follow-up rate of 99.5%. Among 38,660 person-years, incident functional disability was determined in 1316 persons and the number of all-cause deaths without incident functional disability was 471.

We also analyzed the association between consumption of black tea, oolong tea (Chinese tea), or coffee and incident functional disability. In these analyses, we excluded individuals for whom data on consumption of these beverages were missing ($n = 2539$ for black tea, $n = 2626$ for oolong tea, and $n = 1105$ for coffee).

Exposure data

The survey included questions about the frequency of recent average consumption of green tea, oolong tea, black tea, coffee, and 36 food items, as well as items on history of disease, blood pressure, educational level, smoking, alcohol drinking, body weight, height, cognitive activity score (18), psychological distress score (K6) (19, 20), time spent walking per day, and motor function score of the Kihon Checklist (21). The frequency of green tea consumption was categorized as never, occasionally, or 1–2, 3–4, or ≥ 5 cups/d. Within the study region, the volume of a typical cup of green tea is 100 mL.

We conducted a validation study of the food-frequency questionnaire in which 113 respondents provided four 3-d food records within 1 y and subsequently responded to the questionnaire. The Spearman rank correlation coefficient between green tea consumption according to the questionnaire and that according to the food records was 0.71 for men and 0.53 for women; the

correlation between consumption measured by the 2 questionnaires administered 1 y apart was 0.63 for men and 0.64 for women (22).

BMI was calculated as the self-reported body weight (in kg) divided by the square of the self-reported body height (in m). The degree of social support available to each individual was assessed by asking the following questions (23): Do you have someone 1) with whom you can talk when you are in trouble, 2) whom you can consult when you do not feel well, 3) who can help you with your daily housework, 4) who can take you to a hospital when you feel ill, and 5) who can take care of you if you become bedridden? This social support questionnaire consisted of 5 questions, each requiring a “yes” or “no” answer. This questionnaire was available only in Japanese. The validity and reliability of the questionnaire had not been evaluated. We also assessed participation in community activities. We asked about how often each respondent participated in the following activities: 1) neighborhood associations; 2) sports, exercise, or hobbies; 3) volunteering for activities related to nonprofit organizations; and 4) any other type of social gatherings. The frequency of these activities was assessed as never, a few times each year, monthly, 2–3 times/mo, 1 time/wk, 2–3 times/wk, and ≥ 4 times/wk. The motor function score of the Kihon Checklist has been previously evaluated and has shown predictive validity of functional disability (21).

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 y pays premiums, and everyone aged ≥ 65 y 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

TABLE 1
Relation between green tea consumption and characteristics of the participants

	Green tea consumption				P value ¹
	<1 cup/d	1–2 cups/d	3–4 cups/d	≥5 cups/d	
<i>n</i>	2318	3141	3978	4551	
Male sex (%)	57.0	48.9	42.5	36.0	<0.001
Age (y)	73.7 ± 6.2 ²	73.9 ± 6.1	73.9 ± 5.9	74.0 ± 5.8	0.152
BMI (kg/m ²)	23.7 ± 3.8	23.6 ± 3.4	23.5 ± 3.2	23.6 ± 3.3	0.319
Psychological distress (%) ³	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 (%) ⁴	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 (%) ⁵	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) ⁶	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

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

² Mean ± SD (all such values).

³ Kessler 6-item psychological distress scale score ≥13.

⁴ Cognitive activity score ≥23.

⁵ Motor function score of the Kihon Checklist <3.

⁶ Excluding alcohol.

TABLE 2
Relation between green tea consumption and incident functional disability¹

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

iables. 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.

Because green tea is the beverage most frequently served at social activities in Japan, its consumption might be merely a surrogate marker of social support or participation in community

TABLE 3Relation between green tea consumption and incident functional disability stratified by social support and community activity subgroup¹

	Green tea consumption				<i>P</i> -trend	<i>P</i> -interaction
	<1 cup/d	1–2 cups/d	3–4 cups/d	≥5 cups/d		
Social support						
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)	0.68 (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						
Participated						
No. of participants	1114	1669	2297	2542		
Primary outcome events [no. (%)]	80 (7.2)	106 (6.4)	122 (5.3)	115 (4.5)		
Age-and sex-adjusted HR (95% CI) ²	1.00 (reference)	0.80 (0.60, 1.08)	0.61 (0.46, 0.82)	0.52 (0.39, 0.70)	<0.001	
Multiple-adjusted HR (95% CI) ³	1.00 (reference)	0.84 (0.62, 1.13)	0.73 (0.54, 0.97)	0.65 (0.48, 0.88)	0.003	0.585
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.

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 associated 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 perception 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 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 multivariate 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 excluded participants with any history of diseases that cause functional disability (stroke, myocardial infarction, hypertension, arthritis, osteoporosis, or fracture), the results also did not change

TABLE 4
Relation between consumption of other beverages and incident functional disability

	Beverage consumption				<i>P</i> -trend
	<1 cup/d	1–2 cups/d	3–4 cups/d	≥5 cups/d	
Oolong tea (Chinese tea)					
No. of participants	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	1.00 (reference)	1.12 (0.83, 1.52)	0.58 (0.32, 1.05)	0.94 (0.54, 1.63)	0.387
Multiple-adjusted HR (95% CI) ²	1.00 (reference)	1.47 (1.07, 2.03)	0.77 (0.42, 1.40)	1.25 (0.71, 2.18)	0.354
Black tea					
No. of participants	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	1.00 (reference)	1.11 (0.87, 1.41)	0.61 (0.34, 1.11)	0.65 (0.24, 1.74)	0.323
Multiple-adjusted HR (95% CI) ²	1.00 (reference)	1.23 (0.96, 1.59)	0.82 (0.45, 1.51)	1.01 (0.37, 2.75)	0.567
Coffee					
No. of participants	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	1.00 (reference)	0.83 (0.73, 0.94)	0.82 (0.63, 1.07)	0.92 (0.67, 1.27)	0.023
Multiple-adjusted HR (95% CI) ²	1.00 (reference)	0.90 (0.79, 1.03)	0.93 (0.72, 1.22)	1.02 (0.74, 1.41)	0.408

¹ Adjusted as for model 1 in Table 2.

² Adjusted as for model 4 in Table 2.

substantially. The multivariate HRs (model 4) were 1.00 (reference) for <1 cup/d, 0.89 (95% CI: 0.66, 1.20) for 1–2 cups/d, 0.69 (95% CI: 0.51, 0.94) for 3–4 cups/d, and 0.72 (95% CI: 0.53, 0.98) for ≥5 cups/d ($n = 4954$; data not shown).

To confirm whether there was a relation between green tea consumption and incident functional disability, irrespective of social support or participation in community activities, we also conducted stratified analyses for these 2 factors (*see Table 3*). The inverse association was observed irrespective of social support or participation in community activities ($P = 0.103$ for interaction with social support, $P = 0.585$ for interaction with community activities).

The multiple-adjusted HRs for the primary outcome event according to frequency of consumption of oolong tea, black tea, and coffee are compared in **Table 4**. We observed a weak association between coffee consumption and incident functional disability in age- and sex-adjusted models (P -trend= 0.023). However, there were null associations for consumption of oolong tea, black tea, or coffee in multiple-adjusted models.

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 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 in the elderly (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, 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 Yoshiko Nakata, Mika Wagatsuma, and Yuko 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.

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