Ⅳ．研究成果の刊行に関する一覧

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The predictive power of physical function assessed by questionnaire and physical performance measures for subsequent disability

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ABSTRACT. ***Background and aims:*** *To compare the predictive power of physical function assessed by questionnaire and physical performance measures for subsequent disability in community-dwelling elderly persons.* ***Methods:*** *Prospective cohort study. Participants were 813 aged 70 years and older, elderly Japanese residing in the community, included in the Tsurugaya Project, who were not disabled at the baseline in 2003. Physical function was assessed by the questionnaire of "Motor Fitness Scale". Physical performance measures consisted of maximum walking velocity, timed up and go test (TUG), leg extension power, and functional reach test. The area under the curve (AUC) of the receiver operating characteristic curve for disability was used to compare screening accuracy between Motor Fitness Scale and physical performance measures. Incident disability, defined as certification for long-term care insurance, was used as the endpoint.* ***Results:*** *We observed 135 cases of incident disability during follow-up. The third or fourth quartile for each measure was associated with a significantly increased risk of disability in comparison with the highest quartile. The AUC was 0.70, 0.72, 0.70, 0.68, 0.69 and 0.74, for Motor Fitness Scale, maximum walking velocity, TUG, leg extension power, functional reach test, and total performance score, respectively.* ***Conclusions:*** *The predictive power of physical function assessed by the Motor Fitness Scale was equivalent to that assessed by physical performance measures. Since Motor Fitness Scale can evaluate physical function safely and simply in comparison with physical performance tests, it would be a practical tool for screening persons at high risk of disability.*
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INTRODUCTION

It is important for geriatricians in daily practice to be able to identify persons at high risk of disability. As tools for screening of high-risk persons, two methods are available: direct measurement of physical performance, and self-reported questionnaire.

Several studies have reported that physical performance measures can predict the onset of incident disability in non-disabled persons (1-7). However, acquisition of physical performance data is associated with certain disadvantages, such as time constraints, the need for adequate space or special equipment, and the risk of potential

Key words: Community-dwelling elderly persons, disability, epidemiology, physical function, questionnaire.
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injury (8). Conversely, questionnaires can evaluate physical function safely and simply, require no space or special equipment, and carry a negligible risk of accident. However, only a few studies have investigated the ability of physical function, as assessed by questionnaire, to predict physical function decline or subsequent disability (9-11).

Kinugasa et al. (12) developed a 14-item questionnaire-style scale, Motor Fitness Scale with three subscales: mobility, strength, and balance. Since the reliability, construct validity, and discriminant validity of the scale have been fully confirmed, it may represent a suitable tool for screening of individuals at high risk of physical disability. However, previous studies have not examined the accuracy of the Motor Fitness Scale for predicting the risk of disability. If the predictive power of physical function, as assessed by questionnaire, for subsequent disability were equivalent to that of physical performance measures in community-dwelling elderly persons, then acquisition of data for assessing the risk of disability would become considerably simpler and safer.

The purpose of this study was to compare the predictive power of physical function, as assessed by the questionnaire-style Motor Fitness Scale, with physical performance data obtained from tests for subsequent disability in community-dwelling Japanese elderly.

METHODS

Subjects

The Tsurugaya Project was a Comprehensive Geriatric Assessment (CGA) conducted on community-dwelling elderly persons aged 70 years or older, resident in Sendai, Japan (13-20).

The Project was carried out in 2002 and 2003. As we obtained data on Motor Fitness Scale only in 2003, we used those data for the present study. In 2003, from a total of 2925 participating residents of Tsurugaya aged 70 years or older, 962 (32.9%) participated in the survey. The CGA is a structured approach for measuring physical, mental and social functioning of elderly persons, in order to assess early deterioration which may necessitate long-term care (21, 22). Of the 962 participants, 941 gave their consent to use of information in the survey, and 927 gave consent to use of information on their certification for long-term care insurance (LTCI). We excluded 82 participants who had already been certified for LTCI, and 32 for whom physical function data could not be obtained at baseline. As a result, we analysed 813 participants (396 men, 417 women) in the present study. The study protocol was approved by the Ethics Committee of Tohoku University School of Medicine.

Exposure measures

The baseline survey questionnaire contained items on basic personal health, Motor Fitness Scale and the Mini-Mental State Examination (MMSE) (23).

Table 1 - *Items and dimensions of Motor Fitness Scale.*

Mobility	
1.	I can walk up to and down from the second floor.
2.	I can walk up to the second floor without getting out of breath.
3.	I can jump up in the air so that both feet are clearly off the floor at the same time.
4.	I can run 20 steps.
5.	I can pass another person who is walking ahead of me.
6.	I can keep walking for over 30 minutes.
Strength	
7.	I can lift something weighing 10 pounds (e.g., a 1-gallon milk bottle).
8.	I can carry something weighing 20 pounds (e.g., two 1-gallon milk bottles).
9.	I can pick up a fallen bicycle.
10.	I can open a screw-type bottle cap.
Balance	
11.	I can touch the floor with my fingertips while standing with knees straight.
12.	I can put on socks, slacks, or a skirt while standing with no support.
13.	I can stand up from a chair without using my hands.
14.	I can stand on my toes without support.

Motor Fitness Scale. Kinugasa and Nagasaki (12) reported that Motor Fitness Scale has a unidimensional structure consisting of three subscales: Mobility, Strength, and Balance. Its 14 items are shown in Table 1. The scale has high internal consistency and test-retest reliability. High discriminant validity, with subjects' age and gender and construct validity, with subjects' health status and level of sports participation, were confirmed for both Motor Fitness Scale and the summary physical performance score. Responses to the items consisted of simply "yes" (able to perform a specific action at present) or "no" (unable), with a score of 1 for every "yes", and 0 for every "no". If subjects were not used to performing a certain action, they were asked whether they thought they would be able to do it or not. The scale score was the sum total of the 14 items, or the number of items with a "yes" answer, to confirm the score (maximum 14 points).

Physical Performance Measures

Physical performance measures consisted of maximum walking velocity, timed up and go test (TUG) (24), leg extension power, and functional reach test (25). To determine maximum walking velocity, we asked subjects to walk along a straight walkway of 16 meters (m) on a flat floor once, at their maximum speed. Maximum walking velocity was measured over a 10-m distance between marks placed 3 and 13 m from the start of the walkway. We used the better results of two trials for analysis. The TUG test was originally developed as a clinical measure of balance in elderly people (24). It measures the time taken to stand up from an armchair, walk a distance of 3 m, turn, walk back to the chair, and sit down, all at a comfortable and safe speed. If necessary, subjects used their customary walking aids. Functional reach is a dynamic measure of stability during a self-initiated movement (25), and is defined as the distance a subject can reach forward beyond arm's length while maintaining a fixed base of support while standing. A safety handrail was mounted just in front of the subject. For testing leg extension power, subjects were placed well back on a seat, and their waists were fixed with a belt. The knee joint was angled at 90°. Isometric contractions each lasting 5 sec were carried out, separated by 15-sec rest intervals. Peak power was detected, calculated, and recorded in watts on a microcomputer (Aneropress 3500, Combi Wellness, Tokyo). The average of the two highest measurements among 5 trials was recorded as 'isometric strength performance'. To minimize differences in body mass, leg extension power was expressed as the average peak of the leg relative to body weight (W/kg) (16). All performances were assessed by trained observers.

We scored physical performance measures according to gender-specific quartiles. That is, from the lowest to the highest quartile, a score of 0-3 was assigned for each physical performance measure. The sum of these scores (0-12 points) was total performance score.

Other Measures

Cognitive function was tested with the Japanese version of the 30-point MMSE (23), administered by specially trained research assistants. The MMSE includes questions on orientation relative to time and place, registration, attention, calculation, recall, language, and visual construction. This screening test was originally created for a clinical setting (23) and is now used extensively in epidemiologic studies (26). Higher MMSE scores indicate higher cognitive function, and the maximum score is 30. Analyses were conducted with two cut-off points to define different levels of cognitive impairment. The initial cut-off was <28, which we regarded as mild cognitive impairment, and the second was <26, considered to indicate relatively severe cognitive impairment (18). A score of <26 points on the MMSE generally indicates cognitive impairment (27).

Outcome measurements

We defined incident disability as certification for LTCI. The LTCI system was launched as a national insurance system in Japan in April 2000 (28-31). Individuals living in Japan aged ≥65 years who need care are eligible for benefits under the LTCI (28). To receive such care, they must apply for insurance to the municipality, and an on-site assessment is performed for physical and mental status, activities of daily living (ADL) and other parameters. The forms are processed by computer, and individuals are classified automatically as either warranting LTCI certification or not. If they are certified as eligible, the initial assessment system classifies them into seven levels of care, according to need. The criteria for LTCI certification are thus unified all over Japan. A community-based study has demonstrated that levels of LTCI certification are well correlated with individual ADL and MMSE scores (32).

Follow-up survey

We obtained information on LTCI certification and mortality from Sendai City municipal government, which provided information on whether participants had given their informed consent to its use. We provided the name, gender, date of birth, and address of all participants annually to the municipal government, who then checked the list and provided us with information regarding care level and the date of initial certification. The incidence of LTCI certification was defined as certification of a person for any level of care.

Statistical analysis

We allocated subjects into quartiles according to each score measured at baseline, and treated the best group as the reference group. We calculated to compare Motor Fitness Scale scores with total performance scores that mean and standard deviation of total performance scores according to Motor Fitness Scale scores and gender. We also calculated Spearman's rank correlation coefficient between the total score of Motor Fitness Scale and physical performance measures according to gender and MMSE subgroup. Kaplan-Meier curves were used to derive estimates of survival without disability as 4-year survival curves according to the quartiles of Motor Fitness Scale score. The cut-off values of Motor Fitness Scale scores were as follows: 1 (score 14 for men and women), 2 (score 13 for men and women), 3 (score 12 for men and 10-12 for women), and 4 (score 0-11 for men and 0-9 for women). The Kaplan-Meier estimates of survival curves according to Motor Fitness Scale score quartiles were calculated and compared by the log-rank test. The study endpoint was determined as incident disability. Cox proportional hazards regression analysis was used to calculate hazard ratios (HRs) and 95% confidence intervals (CIs). Multivariate-adjusted HRs were adjusted for age (continuous variable) and gender (male, female).

Receiver operating characteristic (ROC) curves were also obtained. For this purpose, we calculated the probability score for disability (LTCI certification) and that for LTCI certification or mortality according to Motor Fitness Scale score, total performance score, and physical performance measures with the logistic regression model. The area under the curve (AUC) of the ROC curves was used to compare screening accuracy among Motor Fitness Scale, physical performance measures, and total performance scores. In additional analyses, we also included

Table 2 - *Baseline characteristics of participants.*

	All	Men	Women
Number of participants, n (%)	813	396 (48.7)	417 (51.3)
Age, mean±SD	75.6±4.4	75.3±4.1	75.8±4.7
Height, cm, mean±SD	155.5±9.1	162.9±5.7	148.5±5.4
Weight, kg, mean±SD	58.6±10.4	63.9±9.3	53.5±8.7
BMI, kg/m^2, mean±SD	24.1±3.3	24.1±3.1	24.2±3.6
Maximum walking velocity, m/s, mean±SD	1.8±0.3	1.9±0.3	1.7±0.3
TUG, seconds, mean±SD	9.2±1.9	8.9±1.7	9.4±2.0
Leg extension power, W/kg, mean±SD	8.4±4.6	11.1±4.1	5.9±3.4
Functional reach test, cm, mean±SD	29.3±5.6	30.4±5.7	28.2±5.4
Total performance score, mean±SD	6.1±3.3	6.1±3.2	6.1±3.5
MMSE*, mean±SD	28.2±2.2	28.3±2.2	28.1±2.3

SD: standard deviation; BMI: body mass index; TUG: timed up and go test; MMSE: mini-mental state examination. *Data were missing, and 803 participants (390 men, 413 women) were examined.

death as the endpoint. All statistical analyses were performed with SAS version 9.1 (SAS Inc., Cary, NC) and STATA SE version 10 (Stata Corp., TX). All reported comparisons are two-sided, and differences at $p<0.05$ were accepted as statistically significant.

In addition, we estimated whether Motor Fitness Scale could predict disability among elderly persons with cognitive impairment. We estimated the relationship between Motor Fitness Scale score quartile and disability according to MMSE subgroup, which was divided into a high MMSE group (score 28-30), representing higher cognitive function, a middle group (score 26-27) representing mild cognitive impairment, and a low group (score 0-25) representing severe cognitive impairment. Cox proportional hazards regression analysis was used to calculate the HRs and 95% CIs. Therefore, in additional analyses, we also included death as the endpoint.

RESULTS

Baseline characteristics of participants

The baseline characteristics of participants are shown in Table 2. Of the 813 participants (396 men, 417 women), the mean age for men was 75.3±4.1 years and that for women was 75.8±4.7 years. The mean scores for physical functions or the Motor Fitness Scale were higher for men than for women.

Relationship between total scores of Motor Fitness Scale and physical performance measures including total performance scores

The means and standard deviations of total performance scores according to Motor Fitness Scale scores and gender are shown in Table 3. Spearman's rank correlation coefficient between the total score of Motor Fitness Scale and physical performance measures for men were 0.31, -0.29, 0.37, 0.28 and 0.41, for maximum walking velocity, TUG, leg extension power, functional reach test, and total performance scores, respectively (all $p<0.0001$). Corresponding values for women were 0.53, -0.45, 0.49, 0.31, and 0.55 (all $p<0.0001$). Thus, the total scores of Motor Fitness Scale correlated with both physical performance measures and total performance scores. Spearman's rank correlation coefficient between Motor Fitness Scale scores and according to MMSE subgroup was also calculated, and was 0.47 ($p<0.0001$) in the high and middle groups (score 26-30) and 0.56 ($p<0.0001$) in the low group (score 0-25).

Table 3 - *Mean and standard deviation of total performance score according to Motor Fitness Scale score and gender.*

Motor Fitness Scale (score)	All		Men		Women	
	n	Mean±SD	n	Mean±SD	n	Mean±SD
0	-	-	-	-	-	-
1	2	0.5±0.7	-	-	2	0.5±0.7
2	-	-	-	-	-	-
3	1	0.0±0.0	-	-	1	0.0±0.0
4	10	2.9±3.1	3	2.0±3.5	7	3.3±3.1
5	9	2.3±2.0	-	-	9	2.3±2.0
6	11	1.6±1.8	5	0.6±0.9	6	2.5±2.0
7	17	3.4±2.8	6	3.2±3.2	11	3.5±2.8
8	30	2.8±2.6	8	2.6±2.6	22	2.9±2.6
9	31	3.1±2.0	10	3.3±2.2	21	3.0±2.0
10	51	3.8±2.9	21	3.3±2.5	30	4.2±3.2
11	56	4.8±3.1	23	4.1±2.8	33	5.2±3.2
12	119	5.9±2.9	54	5.9±2.8	65	5.8±3.0
13	214	6.8±3.0	137	6.6±2.9	77	7.2±2.9
14	262	7.7±2.9	129	7.3±2.8	133	8.1±2.9

n: number of participants; SD: standard deviation. Spearman's rank correlation coefficient between Motor Fitness Scale score and total performance score: men 0.41 ($p<0.0001$), women 0.55 ($p<0.0001$).

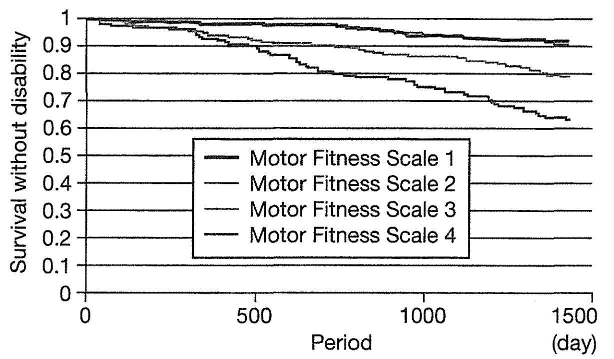

Fig. 1 - *Kaplan-Meier curves for survival without disability, as assessed by LTCI certification according to Motor Fitness Scale scores. LTCI: long-term care insurance; n: number of participants.*

Age-gender-specific median (interquartile range) total scores for Motor Fitness Scale

Among whole participants, the median values of Motor Fitness Scale (interquartile range) were 13 (12-14), 13 (10-14) and 12 (10-13) at age of 70-74, 75-79, and 80-years, respectively. Corresponding values were 13 (12-14), 13 (12-14) and 13 (10-13) among men, and 13 (12-14), 12 (9-13) and 12 (8-13) among women. The median total Motor Fitness Scale scores were inversely correlated with older age, and were higher for men than for women in all age groups.

Risk of disability as assessed by LTCI certification from Motor Fitness Scale, physical performance measures, and total performance scores

During the 4-year follow-up, 135 cases of incident dis-

Table 4 - *Hazard ratios (HRs) of disability (LTCI certification) according to Motor Fitness Scale, physical performance measures, and total performance score (quartile frequency categories).*

				Disability (LTCI Certification)			LTCI certification + Death		
	Men	Women	n	Events	HR†	95% CI	Events*	HR†	95% CI
Motor Fitness Scale (score)	14	14	262	22	1.00	(reference)	29 (9)	1.00	(reference)
	13	13	214	20	0.95	(0.52-1.75)	27 (12)	0.97	(0.57-1.65)
	12	10-12	182	38	2.05	(1.20-3.50)	43 (7)	1.91	(1.18-3.09)
	0-11	0-9	155	55	3.04	(1.80-5.12)	64 (18)	2.93	(1.85-4.66)
					p for Trend < 0.0001			p for Trend < 0.0001	
Maximum walking velocity (m/s)	2.08-	1.85-	213	14	1.00	(reference)	20 (8)	1.00	(reference)
	1.88-2.07	1.66-1.84	208	22	1.47	(0.75-2.87)	32 (12)	1.52	(0.87-2.67)
	1.66-1.87	1.48-1.65	197	34	2.25	(1.20-4.21)	40 (10)	1.88	(1.10-3.23)
	0-1.65	0-1.47	195	65	3.66	(2.00-6.69)	71 (16)	3.02	(1.79-5.08)
					p for Trend < 0.0001			p for Trend < 0.0001	
TUG (s)	0-7.73	0-8.09	202	15	1.00	(reference)	20 (8)	1.00	(reference)
	7.74-8.64	8.10-9.13	203	22	1.31	(0.68-2.52)	31 (11)	1.41	(0.80-2.48)
	8.65-9.60	9.14-10.35	204	34	1.86	(1.01-3.42)	41 (10)	1.73	(1.01-2.97)
	9.61-	10.36-	204	64	2.94	(1.63-5.31)	71 (17)	2.65	(1.58-4.46)
					p for Trend < 0.0001			p for Trend < 0.0001	
Leg extension power (W/kg)	13.9-	8.3-	208	10	1.00	(reference)	15 (6)	1.00	(reference)
	11.3-13.8	6.1-8.2	204	28	2.39	(1.16-4.95)	32 (6)	1.89	(1.02-3.50)
	8.6-11.2	3.8-6.0	203	39	3.06	(1.51-6.18)	49 (14)	2.72	(1.51-4.90)
	0-8.5	0-3.7	198	58	3.94	(1.95-7.95)	67 (20)	3.34	(1.85-6.01)
					p for Trend < 0.0001			p for Trend < 0.0001	
Functional reach test (cm)	34.6-	31.9-	205	17	1.00	(reference)	21 (8)	1.00	(reference)
	31.0-34.5	28.3-31.8	204	22	1.16	(0.61-2.18)	28 (6)	1.21	(0.68-2.13)
	26.2-30.9	24.9-28.2	209	34	1.57	(0.87-2.83)	44 (16)	1.73	(1.02-2.92)
	0-26.1	0-24.8	195	62	2.45	(1.39-4.34)	70 (16)	2.46	(1.47-4.13)
					p for Trend < 0.0001			p for Trend < 0.0001	
Total performance score (score)	8-12	9-12	272	12	1.00	(reference)	18 (9)	1.00	(reference)
	6-7	6-8	200	29	2.90	(1.47-5.70)	38 (10)	2.66	(1.51-4.68)
	4-5	3-5	168	29	3.11	(1.57-6.15)	35 (10)	2.69	(1.51-4.79)
	0-3	0-2	173	65	6.03	(3.13-11.63)	72 (17)	4.89	(2.81-8.51)
					p for Trend < 0.0001			p for Trend < 0.0001	

LTCI: long-term care insurance; n: number of participants; HR: hazard ratio; CI: confidence intervals; TUG: timed up and go test. *Including deaths (numbers in brackets). †Cox proportional hazards regression analysis was used to calculate hazard ratios (HRs) adjusted for age (continuous variable) and gender.

ability (54 men, 81 women) were observed. When death was included as an outcome, we observed 163 outcome events (75 men, 88 women) determined by disability or mortality.

The Kaplan-Meier curves for survival without disability, as assessed by LTCI certification according to Motor Fitness Scale, are shown in Figure 1. We allocated subjects to quartiles based on Motor Fitness Scale scores at baseline. After the 4-year follow-up, rates of survival without disability according to Motor Fitness Scale categories were 91.6% (category 1), 90.7% (2), 79.1% (3) and 64.5% (4). A significantly lower rate of survival without disability was observed in Motor Fitness Scale categories 3 or 4, in comparison with those in category 1 (category 1 *vs* 3 log-rank test, $p=0.0001$, category 1 *vs* 4 log-rank test, $p<0.0001$). A lower Motor Fitness Scale score was associated with a lower rate of survival without disability.

The HRs of incident disability according to Motor Fitness Scale, physical performance measures, and total performance scores are shown in Table 4. All the physical performance measures including Motor Fitness Scale scores significantly predicted the risk of disability (*p* for trend, all <0.0001). As seen for the HRs adjusted for age and gender, the third or fourth quartile for each measure indicated a significantly increased risk of disability in comparison with the highest performance level. We found that the relationship was similar when we used LTCI certification (disability) or mortality as an endpoint.

ROC curves for predicting disability are shown in Figure 2. The AUC ± standard error (SE) was 0.70±0.03 for Motor Fitness Scale, 0.72±0.03 for maximum walking velocity, 0.70±0.03 for TUG, 0.68±0.02 for leg extension power, 0.69±0.03 for functional reach test, and 0.74±0.02 for total performance score. This relationship was similar when we used disability or mortality as an endpoint (AUC±SE: 0.68±0.02 for Motor Fitness Scale, 0.69±0.02 for maximum walking velocity, 0.67±0.02 for TUG, 0.66±0.02 for leg extension power, 0.67±0.02 for functional reach test, and 0.72±0.02 for total performance score). Although the total performance score showed the largest AUC, the AUC for Motor Fitness Scale was equivalent to that of the physical performance measures.

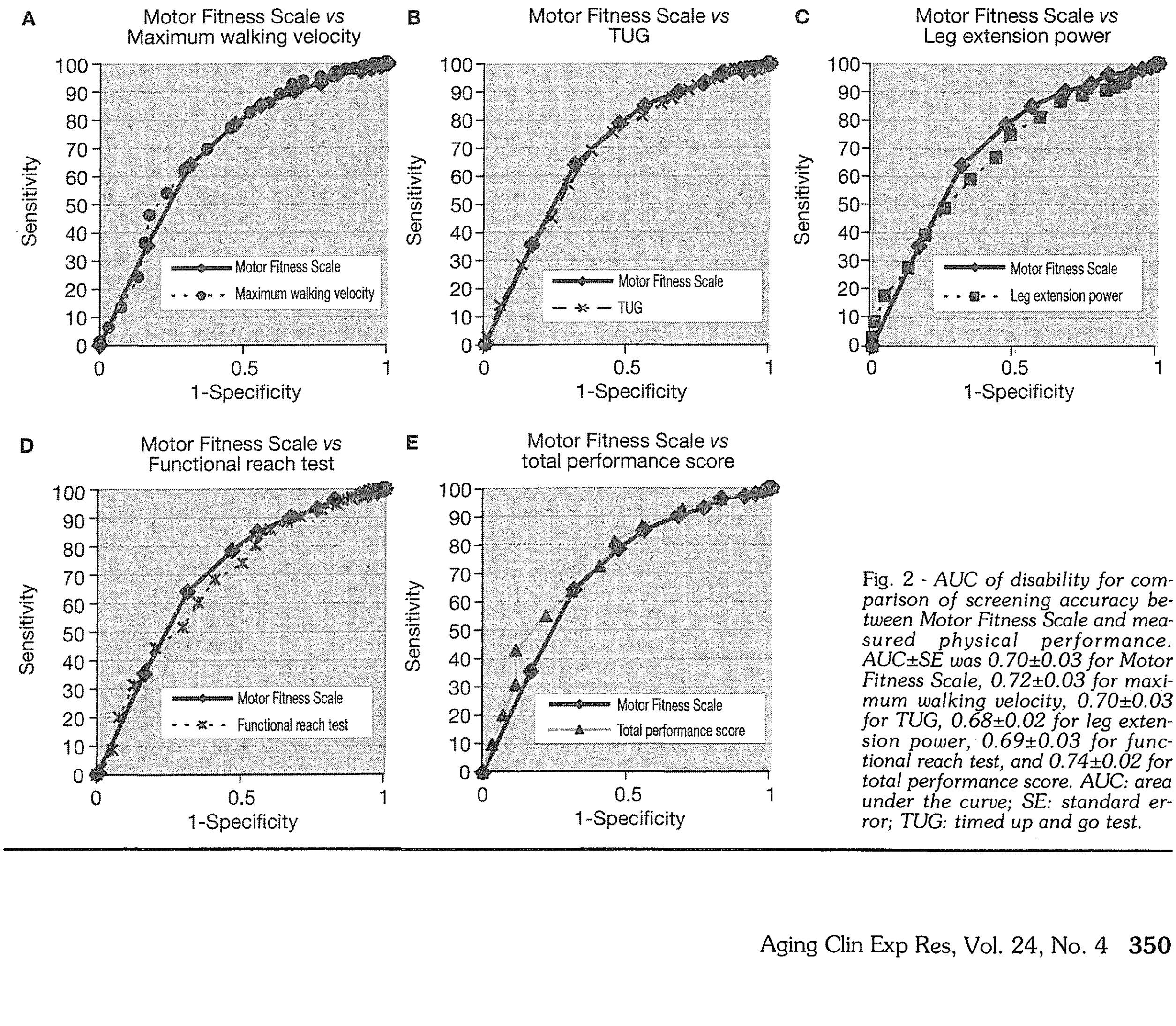

Fig. 2 - *AUC of disability for comparison of screening accuracy between Motor Fitness Scale and measured physical performance. AUC±SE was 0.70±0.03 for Motor Fitness Scale, 0.72±0.03 for maximum walking velocity, 0.70±0.03 for TUG, 0.68±0.02 for leg extension power, 0.69±0.03 for functional reach test, and 0.74±0.02 for total performance score. AUC: area under the curve; SE: standard error; TUG: timed up and go test.*

Table 5 - *Relation between Motor Fitness Scale quartile and disability (LTCI certification) according to MMSE subgroup.*

	MMSE (28-30)				MMSE (26-27)				MMSE (0-25)			
	n	Events	HR†	95% CI	n	Events	HR†	95% CI	n	Events	HR†	95% CI
Motor Fitness Scale 1	210	14	1.00	(reference)	34	2	1.00	(reference)	16	6	1.00	(reference)
Motor Fitness Scale 2	162	10	0.81	(0.36-1.82)	31	5	1.97	(0.38-10.38)	17	5	0.98	(0.30-3.27)
Motor Fitness Scale 3	137	23	2.12	(1.07-4.19)	24	8	4.40	(0.92-21.09)	19	7	0.90	(0.30-2.70)
Motor Fitness Scale 4	94	30	3.66	(1.89-7.12)	36	17	5.96	(1.31-27.17)	23	7	0.60	(0.19-1.90)
	p for Trend < 0.0001				*p* for Trend 0.02				*p* for Trend 0.18			

LTCI: long-term care insurance; MMSE: mini-mental state examination; n: number of participants; HR: hazard ratio; CI: confidence intervals. †Cox proportional hazards regression analysis was used to calculate hazard ratios (HRs) adjusted for age (continuous variable) and gender.

Relationship between Motor Fitness Scale quartile and disability (LTCI certification) according to MMSE subgroup

The relationship between Motor Fitness Scale quartile and disability according to MMSE subgroup is shown in Table 5. A lower quartile indicates a significantly increased risk of disability compared with a higher quartile for high MMSE group (score 28-30) (p for trend <0.0001) and the middle one (score 26-27) (p for trend =0.02). However, an inverse association was not apparent in low MMSE group (score 0-25) (p for trend =0.18). This relationship was similar when we used disability or mortality as an endpoint. We analysed participants in the higher cognitive function subgroup with MMSE scores of >26, and calculated the probability score for disability according to Motor Fitness Scale score and total performance score. The AUC of the former was equivalent to that of total performance (AUC±SE: 0.72±0.03 for Motor Fitness Scale score and 0.74±0.02 for total performance score).

DISCUSSION

In this study, we found that both Motor Fitness Scale and all physical performance measures predicted the risk of incident disability. Although the total performance score had the largest AUC, that of Motor Fitness Scale score was equivalent to that of the physical performance measures.

The self-reported questionnaire can evaluate physical performance simply, safely and comprehensively. The Motor Fitness Scale is verified as reliable, with construct validity and discriminant validity equivalent to those of physical performance measures (12). We also showed that this simple questionnaire had predictive validity. Several studies have also reported that the questionnaire can predict decline of physical function (9, 10). Fried et al. (9) reported that self-reported level of function was able to predict functional decline as well as measured data for walking speed, balance and strength. Studenski et al. (10) also compared the ability of predicting functional decline between self-reported measurements and performance measures, and noted that, in general, measured performance, alone or in combination with self-reported data, was better able to predict outcomes than self-reporting alone. However, in terms of ADL decline, which would be similar to our definition of disability, self-reported data were superior to gait speed alone and the three-item lower extremity performance battery in predicting functional decline as disability. Thus, our findings that physical function assessed by questionnaire (Motor Fitness Scale) predicted incident disability and that the predictive power of Motor Fitness Scale assessed from relative risk and the AUC of the ROC curves was equivalent to that of physical performance measures, were consistent with these previous studies. The better predictive validity of physical function assessed with Motor Fitness Scale may be explained by its higher correlation with physical performance measures. In addition, according to a recent study, self-reported physical function is also influenced by personal and health characteristics which relate to frailty (33). Thus, the high predictive validity of physical function assessed by Motor Fitness Scale may be influenced not only by an objective physical function but also by other factors related to frailty.

Other screening batteries employing simple and safe methods have also been developed. Ensrud et al. (34, 35) compared the predictive validity of a simple frailty index, using as components weight loss, inability to rise from a chair 5 times without using the arms, and reduced energy level (Study of Osteoporotic Fractures [SOF index]) with that of the Cardiovascular Health Study (CHS) index, employing as components unintentional weight loss, poor grip strength, reduced energy level, slow walking speed, and low level of physical activity. The simple SOF index predicted the risk of falls, disability, fracture and mortality, and was considered to provide a useful definition of frailty for identifying older persons at risk of adverse health outcomes in clinical practice. Mänty et al. (11) also reported the construct and predictive validity of a self-reported measure of preclinical mobility limitation. Although we were unable to compare our method directly with theirs, the direction of effort – that is, to establish simpler and safer methods for screening high-risk participants – was consistent with ours.

Because it is questionable whether the questionnaire survey we employed was suitable for participants with impaired cognitive function, we estimated the relationship between Motor Fitness Scale quartile and disability according to MMSE subgroup. First we checked Spearman's correlation between Motor Fitness Scale and total performance score according to MMSE subgroup (<26 and ≥26). We found that for both high and middle MMSE subgroups, Motor Fitness Scale correlated well with total performance score. However, no inverse association was apparent in the low MMSE group (score <26), generally indicative of cognitive impairment. This lack of association between the Motor Fitness Scale and disability in low, scoring MMSE participants may be due to the generally higher LTCI certification risk in lower MMSE participants. As low MMSE participants may be certified irrespective of their physical function, no apparent risk difference between the low group of Motor Fitness Scale and the high group was observed. Therefore, in elderly persons with cognitive impairment, the predictive power of physical function assessed by the Motor Fitness Scale is weak.

This study has several strengths. First, we measured Motor Fitness Scale with a questionnaire and the physical performance parameters simultaneously, and compared their values for predicting the risk of disability. Second, there were few drop-out subjects, and we followed-up participants for a long period. Third, since the LTCI certification system has been adopted nationwide in Japan, it is used to determine disability on the basis of nationally unified criteria with computer-based initial assessment. This computer-aided needs assessment has made it possible to examine a large number of elderly persons efficiently and objectively (30). Levels of LTCI certification were also associated with individuals' ADL and MMSE scores (32). LTCI certification is associated not only with disability in terms of physical function, but also in terms of cognitive function. Therefore, we believe that LTCI certification is a comprehensive indicator of disability.

This study also had some limitations. First, we did not know causes of death or reasons for LTCI certification. Second, it is possible that our results cannot be generalized to populations outside Japan, where LTCI does not exist. However, as LTCI certification was well correlated with the Barthel Index, we considered that the former is a good indicator of ADL decline. For generalization of Motor Fitness Scale, further study is required to confirm our findings.

In conclusion, Motor Fitness Scale can predict the risk of disability with an accuracy equivalent to measured physical performance data. Since it can evaluate physical function safely and simply in comparison with measured physical performance, it is a practical tool for screening individuals at high risk of disability.

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Role of authors. M. Hoshi: study concept and design, analysis and interpretation of data, preparation of manuscript. A. Hozawa: study concept and design, acquisition of baseline and follow-up data, analysis and interpretation of data, preparation of manuscript. S. Kuriyama, N. Nakaya, K. Ohmori-Matsuda: acquisition of baseline and follow-up data, analysis and interpretation of data. T. Sone: acquisition of follow-up data. M. Kakizaki, acquisition of follow-up data and interpretation of data. K. Niu, K. Fujita: acquisition of baseline data. S. Ueki, H. Haga: study concept and design, acquisition of baseline data and supervision. R. Nagatomi: acquisition of baseline data and supervision. I. Tsuji: acquisition of baseline and follow-up data, analysis and interpretation of data, obtaining research funding, and supervision.

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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* 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

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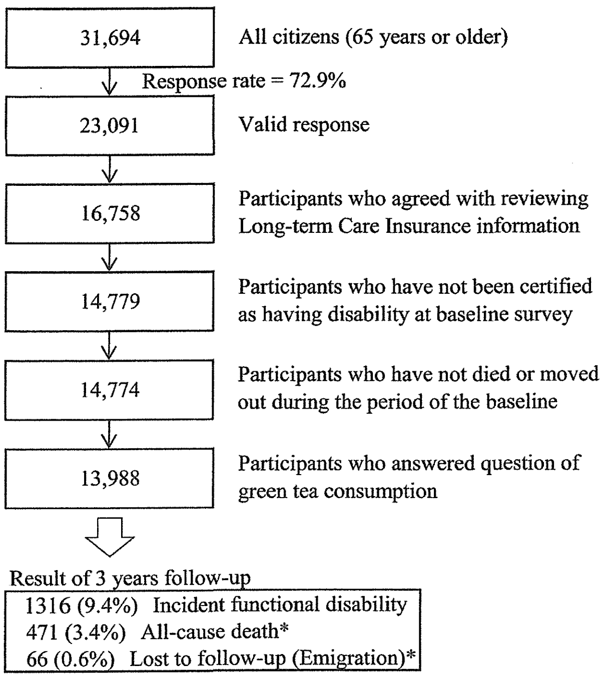

FIGURE 1. Flowchart of study participants: the Ohsaki Cohort 2006 Study. *Without experiencing incident functional disability.

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				
	<1 cup/d	1–2 cups/d	3–4 cups/d	≥5 cups/d	*P* value[1]
n	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.

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TABLE 2
Relation between green tea consumption and incident functional disability[1]

Incident functional disability	Green tea consumption <1 cup/d	1–2 cups/d	3–4 cups/d	≥5 cups/d	*P*-trend	*P*-interaction
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/m^2; <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.

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

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TABLE 3
Relation between green tea consumption and incident functional disability stratified by social support and community activity subgroup[1]

	Green tea consumption					
	<1 cup/d	1–2 cups/d	3–4 cups/d	≥5 cups/d	*P*-trend	*P*-interaction
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				
	<1 cup/d	1–2 cups/d	3–4 cups/d	≥5 cups/d	*P*-trend
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

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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 be necessary to confirm the protective effect of green tea against functional disability.

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