Table 1
Baseline characteristics of men according to green tea consumption (December 2006, Ohsaki City, Miyagi Prefecture, Northeastern Japan).[a]

Characteristics	Green tea consumption, cups/day				
	<1 (n=4108)	1–2 (n=4180)	3–4 (n=2395)	≥5 (n=1336)	P-value[b]
Total number of teeth					
0–9	428 (10.4)	356 (8.5)	223 (9.3)	154 (11.5)	<0.0001
10–19	894 (21.8)	770 (18.4)	477 (19.9)	263 (19.7)	
20–24	1283 (31.2)	1352 (32.3)	797 (33.3)	425 (31.8)	
≥25	1503 (36.6)	1702 (40.7)	898 (37.5)	494 (37.0)	
Age, mean (SD), years	52.2 (6.7)	52.7 (6.5)	54.7 (6.5)	56.0 (6.3)	<0.0001
Daily tooth brushing					
<2 times/day	1925 (47.4)	1745 (42.0)	955 (40.2)	574 (43.5)	<0.0001
2 times/day	1716 (42.2)	1826 (44.0)	1066 (44.9)	533 (40.4)	
>2 times/day	424 (10.4)	582 (14.0)	356 (15.0)	213 (16.1)	
Years of education					
<10	442 (11.1)	342 (8.4)	252 (10.8)	181 (14.0)	<0.0001
10–12	2388 (59.9)	2473 (60.6)	1356 (58.1)	748 (57.7)	
≥13	1158 (29.0)	1265 (31.0)	727 (31.1)	367 (28.3)	
Body mass index, kg/m^2					
<18.5	108 (2.7)	78 (1.9)	49 (2.1)	30 (2.3)	0.0001
18.5–22.9	1554 (38.2)	1502 (36.2)	897 (37.7)	492 (37.2)	
23.0–24.9	1009 (24.8)	1115 (26.9)	641 (26.9)	394 (29.8)	
25.0–29.9	1220 (30.0)	1299 (31.3)	734 (30.8)	372 (28.1)	
≥30.0	176 (4.3)	156 (3.8)	61 (2.6)	36 (2.7)	
Time spent walking, h/day					
<1	2689 (66.5)	2881 (69.9)	1632 (69.4)	843 (64.7)	0.0002
≥1	1355 (33.5)	1238 (30.1)	721 (30.6)	461 (35.4)	
History of chronic disease					
Stroke	55 (1.3)	60 (1.4)	36 (1.5)	25 (1.9)	0.57
Myocardial infarction	51 (1.2)	55 (1.3)	33 (1.4)	27 (2.0)	0.19
Diabetes mellitus	323 (7.9)	338 (8.1)	223 (9.3)	121 (9.1)	0.14
Cancer	85 (2.1)	99 (2.4)	71 (3.0)	50 (3.7)	0.0033
Smoking status					
Never	617 (15.3)	757 (18.3)	449 (19.1)	248 (19.0)	<0.0001
Former	1205 (29.8)	1419 (34.4)	842 (35.7)	437 (33.5)	
Current, 1–19 cigarettes/day	586 (14.5)	535 (13.0)	289 (12.3)	151 (11.6)	
Current, ≥20 cigarettes/day	1633 (40.4)	1418 (34.3)	776 (32.9)	469 (35.9)	
Alcohol drinking					
Never	596 (14.7)	494 (11.9)	310 (13.1)	206 (15.6)	<0.0001
Former	287 (7.1)	232 (5.6)	138 (5.8)	104 (7.9)	
Current	3182 (78.3)	3418 (82.5)	1924 (81.1)	1007 (76.5)	
Consumption of sweets (such as *manju*[c], *yokan*[d] or cake)					
<3 times/week	3240 (80.5)	3234 (79.1)	1790 (76.2)	925 (71.3)	<0.0001
≥3 times/week	785 (19.5)	854 (20.9)	558 (23.8)	373 (28.7)	
Daily consumption					
Miso (soybean paste) soup[e]	2875 (70.0)	3227 (77.2)	1937 (80.9)	1102 (82.6)	<0.0001
Soybean products[e]	1182 (29.4)	1470 (35.9)	1035 (43.8)	658 (50.0)	<0.0001
Milk[e]	1163 (28.8)	1286 (31.2)	753 (31.9)	440 (33.8)	0.0018
Total fish, mean (SD), g	40.4 (28.4)	44.1 (29.1)	48.3 (29.1)	54.1 (32.0)	<0.0001
Oolong tea, ≥3cups/day	126 (3.2)	91 (2.4)	69 (3.2)	47 (4.0)	0.025
Black tea, ≥3 cups/day	25 (0.6)	17 (0.5)	28 (1.3)	19 (1.6)	<0.0001
Coffee, ≥3 cups/day	1541 (37.9)	1271 (31.0)	720 (31.0)	359 (28.1)	<0.0001
Total calories, mean (SD), kcal	1590.1 (509.3)	1627.7 (494.0)	1702.6 (515.0)	1734.2 (510.0)	<0.0001

[a] Data were expressed as No. (%) unless otherwise indicated.
[b] P-values calculated by analysis of variance or χ^2 test.
[c] A steamed bean-jam bun.
[d] Sweetened and jellied bean paste.
[e] Almost everyday.

The association appeared to fit a threshold model, such that persons who consume at least one cup of green tea per day might receive some benefit in terms of tooth retention. The catechin content of green tea might be able to explain the threshold association. Dental caries and periodontal disease are the main causes of tooth loss in persons aged over 45 years in Japan (Aida et al., 2006). These diseases are mainly due to the actions of oral bacteria. A number of experimental studies have shown that green tea catechins inhibit oral bacteria (Hirasawa et al., 2002; Sakanaka and Okada, 2004; Smullen et al., 2007), while some experiments have indicated that the concentration of tea catechin conferring the above effect should be more than 100 mg/100 ml (Hirasawa et al., 2002; Otake et al., 1991; Sakanaka and Okada, 2004). A typical preparation of green tea contains a catechin concentration of 50–150 mg/100 ml (Sakanaka and Okada, 2004). Therefore, this amount of catechin contained in one cup of green tea might be sufficient to aid tooth retention.

An inverse dose–response relationship should be observed for any beverage with a weaker catechin concentration, for instance oolong tea (Ooshima et al., 1994). Indeed, we found that ORs for oolong tea indicated an inverse dose–response relationship. Shimada et al. reported that oolong tea contained about 13 mg/100 ml catechin, which was far weaker than that in green tea (Shimada et al., 2004). Because of the low catechin concentration, the amount of catechin contained in one cup of oolong tea is insufficient to reach a level that will inhibit oral bacteria. Hence, in order to be exposed to a level of catechins necessary to prevent tooth loss, many more cups of oolong tea might have to be consumed. Therefore, the results for oolong tea might explain the apparent threshold association for green tea consumption from the viewpoint of the amount of catechin.

Table 2
Baseline characteristics of women according to green tea consumption (December 2006, Ohsaki City, Miyagi Prefecture, Northeastern Japan).[a]

Characteristics	Green tea consumption, cups/day				
	<1 (n=3693)	1–2 (n=4070)	3–4 (n=3026)	≥5 (n=2270)	P-value[b]
Total number of teeth					
0–9	369 (10.0)	355 (8.7)	301 (10.0)	256 (11.3)	<0.0001
10–19	668 (18.1)	708 (17.4)	599 (19.8)	516 (22.7)	
20–24	1107 (30.0)	1184 (29.1)	940 (31.1)	669 (29.5)	
≥25	1549 (41.9)	1823 (44.8)	1186 (39.2)	829 (36.5)	
Age, mean (SD), years	51.3 (6.6)	52.5 (6.7)	54.9 (6.4)	56.7 (5.9)	<0.0001
Daily tooth brushing					
<2 times/day	771 (21.0)	625 (15.4)	443 (14.7)	372 (16.5)	<0.0001
2 times/day	2081 (56.7)	2287 (56.3)	1597 (53.0)	1213 (53.7)	
>2 times/day	821 (22.4)	1150 (28.3)	971 (32.3)	674 (29.8)	
Years of education					
<10	316 (8.9)	298 (7.6)	243 (8.4)	226 (10.4)	0.0015
10–12	1991 (55.8)	2219 (56.3)	1580 (54.3)	1230 (56.5)	
≥13	1262 (35.4)	1428 (36.2)	1087 (37.4)	723 (33.2)	
Body mass index, kg/m^2					
<18.5	208 (5.7)	189 (4.7)	135 (4.5)	104 (4.6)	<0.0001
18.5–22.9	1739 (47.7)	1961 (48.7)	1369 (45.7)	982 (43.6)	
23.0–24.9	729 (20.0)	875 (21.7)	690 (23.1)	484 (21.5)	
25.0–29.9	795 (21.8)	858 (21.3)	679 (22.7)	589 (26.1)	
≥30.0	173 (4.8)	148 (3.7)	120 (4.0)	95 (4.2)	
Time spent walking, h/day					
<1	2566 (71.1)	2866 (71.9)	2170 (73.4)	1554 (70.7)	0.12
≥1	1044 (28.9)	1122 (28.1)	788 (26.6)	644 (29.3)	
History of chronic disease					
Stroke	24 (0.7)	20 (0.5)	16 (0.5)	6 (0.3)	0.24
Myocardial infarction	9 (0.2)	11 (0.3)	14 (0.5)	15 (0.7)	0.037
Diabetes mellitus	145 (3.9)	162 (4.0)	137 (4.5)	133 (5.9)	0.0016
Cancer	133 (3.6)	156 (3.8)	136 (4.5)	142 (6.3)	<0.0001
Smoking status					
Never	2645 (75.0)	3184 (82.6)	2465 (86.6)	1813 (86.3)	<0.0001
Former	297 (8.4)	254 (6.6)	152 (5.3)	110 (5.2)	
Current, 1–19 cigarettes/day	399 (11.3)	296 (7.7)	155 (5.5)	109 (5.2)	
Current, ≥20 cigarettes/day	185 (5.3)	120 (3.1)	73 (2.6)	69 (3.3)	
Alcohol drinking					
Never	1734 (48.4)	1986 (50.3)	1621 (55.9)	1291 (59.9)	<0.0001
Former	271 (7.6)	224 (5.7)	165 (5.7)	143 (6.6)	
Current	1577 (44.0)	1737 (44.0)	1114 (38.4)	720 (33.4)	
Consumption of sweets (such as *manju*[c], *yokan*[d] or cake)					
<3 times/week	2278 (62.6)	2389 (59.5)	1655 (55.7)	1265 (56.7)	<0.0001
≥3 times/week	1364 (37.5)	1628 (40.5)	1314 (44.3)	966 (43.3)	
Daily consumption					
Miso (soybean paste) soup[e]	2469 (67.0)	3068 (75.5)	2401 (79.6)	1808 (79.8)	<0.0001
Soybean products[e]	1698 (46.8)	2194 (54.7)	1839 (61.9)	1491 (67.0)	<0.0001
Milk[e]	1351 (37.0)	1622 (40.2)	1271 (42.6)	946 (42.4)	<0.0001
Total fish, mean (SD), g	37.8 (24.3)	42.0 (24.9)	46.8 (25.5)	51.2 (26.7)	<0.0001
Oolong tea, ≥3 cups/day	198 (5.6)	119 (3.1)	105 (3.7)	91 (4.3)	<0.0001
Black tea, ≥3 cups/day	47 (1.3)	38 (1.0)	46 (1.6)	38 (1.8)	0.035
Coffee, ≥3 cups/day	1538 (42.0)	1360 (33.8)	847 (28.4)	515 (23.4)	<0.0001
Total calories, mean (SD), kcal	1177.2 (299.0)	1231.1 (299.0)	1279.2 (294.9)	1299.0 (303.1)	<0.0001

[a] Data were expressed as No. (%) unless otherwise indicated.
[b] P-values calculated by analysis of variance or χ^2 test.
[c] A steamed bean-jam bun.
[d] Sweetened and jellied bean paste.
[e] Almost everyday.

The ORs for coffee consumption (Table 5) showed that persons who consumed more cups of coffee had a lower number of teeth. Tooth loss in the case of coffee consumption might be due to exacerbation of dental caries by addition of sugar or syrup (Jones et al., 1999), since 44.2% of men and 30.7% of women in this study added sugar or syrup to their coffee. Our analyses stratified by addition of sugar or syrup showed that the effects attributable to sugar or syrup were remarkable for women but almost negligible for men. Therefore, addition of sugar or syrup might be one possible explanation for the remarkable reduction of ORs in women. Furthermore, the non-decreasing ORs of tooth loss for those consuming coffee without sugar or syrup might be explained by the absence of catechin in coffee.

The effects of mouth rinses on tooth retention should be taken into account. If mouth rinsing itself prevents tooth loss, other beverages lacking catechin such as coffee without sugar or syrup might produce effects similar to the result of green tea consumption. However, we did not observe any decrease in ORs for tooth loss among subjects consuming coffee. Hence, mouth rinsing might have no effect on tooth retention.

Study strengths

Our study had several methodological strengths. First, this was a population-based study with a large sample size of 25,078 subjects from the general population in Japan. Second, the validity and reproducibility of green tea consumption among subjects in our previous validation study were reasonably high (Ogawa et al., 2003). Third, many of the subjects drank green tea and were distributed nearly evenly among the four categories of consumption frequency.

Table 3
Odds ratios (ORs) and 95% confidence intervals (CIs) of tooth loss according to green tea consumption (December 2006, Ohsaki City, Miyagi Prefecture, Northeastern Japan).

	Green tea consumption, cups/day				
	<1	1–2	3–4	≥5	*P*-values for trend
Cut-off point: <10 teeth					
	Men				
Number of cases/number of participants	428/4108	356/4180	223/2395	154/1336	
Age-adjusted OR (95% CI)	1.00	0.76 (0.65, 0.88)	0.69 (0.58, 0.83)	0.79 (0.64, 0.96)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	0.87 (0.74, 1.02)	0.81 (0.68, 0.97)	0.82 (0.66, 1.01)	0.0063
	Women				
Number of cases/number of participants	369/3693	355/4070	301/3026	256/2270	
Age-adjusted OR (95% CI)	1.00	0.74 (0.63, 0.87)	0.67 (0.57, 0.79)	0.66 (0.55, 0.79)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	0.87 (0.74, 1.02)	0.81 (0.68, 0.97)	0.75 (0.62, 0.91)	0.0006
Cut-off point: <20 teeth					
	Men				
Number of cases/number of participants	1322/4108	1126/4180	700/2395	417/1336	
Age-adjusted OR (95% CI)	1.00	0.73 (0.67, 0.81)	0.72 (0.64, 0.80)	0.72 (0.63, 0.83)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	0.82 (0.74, 0.91)	0.82 (0.73, 0.92)	0.77 (0.66, 0.89)	<0.0001
	Women				
Number of cases/number of participants	1037/3693	1063/4070	900/3026	772/2270	
Age-adjusted OR (95% CI)	1.00	0.79 (0.71-0.88)	0.76 (0.68-0.85)	0.81 (0.71-0.91)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	0.87 (0.78-0.97)	0.87 (0.77-0.98)	0.89 (0.78-1.01)	0.011
Cut-off point: <25 teeth					
	Men				
Number of cases/number of participants	2605/4108	2478/4180	1497/2395	842/1336	
Age-adjusted OR (95% CI)	1.00	0.80 (0.73, 0.87)	0.81 (0.73, 0.90)	0.76 (0.67, 0.87)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	0.89 (0.81, 0.98)	0.94 (0.84, 1.05)	0.85 (0.74, 0.97)	0.011
	Women				
Number of cases/number of participants	2144/3693	2247/4070	1840/3026	1441/2270	
Age-adjusted OR (95% CI)	1.00	0.80 (0.72, 0.87)	0.83 (0.74, 0.92)	0.80 (0.72, 0.90)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	0.86 (0.78, 0.95)	0.94 (0.84, 1.04)	0.89 (0.79, 1.00)	0.083

[a] The multivariate OR has been adjusted for age (40–44, 45–49, 50–54, 55–59, or 60–64 years), daily tooth brushing (<2, 2, or >2 times/day), years of education (<10, 10–12, or ≥13), body mass index (calculated as weight in kilograms divided by height in meters squared; <18.5, 18.5–22.9, 23.0–24.9, 25.0–29.9, or ≥30.0), time spent walking (<1 or ≥1 h/day), history of stroke, myocardial infarction, diabetes mellitus, and cancer (for each disease, yes or no), smoking status (never, former, currently smoking 1–19, or currently smoking ≥20 cigarettes/day), alcohol drinking (never, former, current), consumption of sweets such as *manju* (a steamed bean-jam bun), *yokan* (sweetened and jellied bean paste), or cake (<3 or ≥3 times/week), daily consumption of *miso* (soybean paste) soup, soybean products, milk (for each food, almost everyday or not), total fish (categorized into quartiles: <21.7, 21.7–47.5, 47.5–53.4, or ≥53.4 g/day for men; <22.8, 22.8–41.3, 41.3–53.4, or ≥53.4 g/day for women), oolong tea, black tea, and coffee (for each beverage, never or occasionally, 1–2, 3–4, or ≥5 cups/day), and total intake of calories (categorized into quartiles: <1265.8, 1265.8–1603.4, 1603.4–1933.2, or ≥1933.2 kcal/day for men; <1027.3, 1027.3–1242.8, 1242.8–1439.0, or ≥1439.0 kcal/day for women).

Study limitations

Several methodological limitations should also be considered when interpreting our results. First, our study had a cross-sectional design and no temporal relationship between green tea consumption and tooth loss can be inferred. However, teeth are not considered to play an indispensable role in drinking green tea, since green tea is a liquid. Therefore, we can reasonably speculate that teeth are retained as a result of consuming green tea. Second, we had no information on the validity of the self-reported number of residual teeth. However, previous studies had shown that the general population was able to provide reasonably accurate estimates of the self-reported number of teeth present (Axelsson and Helgadóttir, 1995; Douglass et al., 1991; Pitiphat et al., 2002). If a large proportion of the subjects gave vague answers in the questionnaires as to the number of their remaining teeth, misclassification regarding green tea consumption would occur. If data containing misclassifications were used for estimation of ORs, the general results would probably have been distorted, and any effect of green tea consumption in decreasing the odds for tooth loss might have been attenuated. Third, we had no information about dental

Table 4
Odds ratios (ORs) and 95% confidence intervals (CIs) of tooth loss according to oolong tea consumption; cut-off point: <20 teeth (December 2006, Ohsaki City, Miyagi Prefecture, Northeastern Japan).

	Oolong tea consumption, cups/day				
	<1	1–2	3–4	≥5	*P*-values for trend
	Men				
Number of cases/number of participants	2966/10,031	171/700	56/231	29/115	
Age-adjusted OR (95% CI)	1.00	0.90 (0.75, 1.08)	0.84 (0.61, 1.14)	0.85 (0.54, 1.30)	0.0019
Multivariate-adjusted OR (95% CI)[a]	1.00	0.93 (0.77, 1.12)	0.87 (0.63, 1.20)	0.85 (0.54, 1.33)	0.042
	Women				
Number of cases/number of participants	3116/10,988	208/815	80/344	54/187	
Age-adjusted OR (95% CI)	1.00	0.99 (0.83, 1.17)	0.77 (0.59, 1.00)	1.07 (0.76, 1.48)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	0.99 (0.83, 1.18)	0.72 (0.55, 0.94)	0.85 (0.60, 1.20)	<0.0001

[a] The multivariate OR has been adjusted for age (40–44, 45–49, 50–54, 55–59, or 60–64 years), daily tooth brushing (<2, 2, or >2 times/day), years of education (<10, 10–12, or ≥13), body mass index (calculated as weight in kilograms divided by height in meters squared; <18.5, 18.5–22.9, 23.0–24.9, 25.0–29.9, or ≥30.0), time spent walking (<1 or ≥1 h/day), history of stroke, myocardial infarction, diabetes mellitus, and cancer (for each disease, yes or no), smoking status (never, former, currently smoking 1–19, or currently smoking ≥20 cigarettes/day), alcohol drinking (never, former, current), consumption of sweets such as *manju* (a steamed bean-jam bun), *yokan* (sweetened and jellied bean paste), or cake (<3 or ≥3 times/week), daily consumption of *miso* (soybean paste) soup, soybean products, milk (for each food, almost everyday or not), total fish (categorized into quartiles: <21.7, 21.7–47.5, 47.5–53.4, or ≥53.4 g/day for men; <22.8, 22.8–41.3, 41.3–53.4, or ≥53.4 g/day for women), green tea, black tea, and coffee (for each beverage, never or occasionally, 1–2, 3–4, or ≥5 cups/day), and total intake of calories (categorized into quartiles: <1265.8, 1265.8–1603.4, 1603.4–1933.2, or ≥1933.2 kcal/day for men; <1027.3, 1027.3–1242.8, 1242.8–1439.0, or ≥1439.0 kcal/day for women).

Table 5
Odds ratios (ORs) and 95% confidence intervals (CIs) of tooth loss according to coffee consumption with or without sugar or syrup; cut-off point: <20 teeth (December 2006, Ohsaki City, Miyagi Prefecture, Northeastern Japan).

	Coffee consumption, cups/day				
	<1	1–2	3–4	≥5	*P*-values for trend
Coffee consumption					
	Men				
Number of cases/number of participants	887/3003	1521/5206	953/3142	335/972	
Age-adjusted OR (95% CI)	1.00	1.12 (1.01, 1.24)	1.30 (1.16, 1.45)	1.58 (1.34, 1.85)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	1.06 (0.96, 1.18)	1.16 (1.03, 1.31)	1.30 (1.10, 1.54)	0.0003
	Women				
Number of cases/number of participants	855/2766	1731/6041	939/3384	313/1025	
Age-adjusted OR (95% CI)	1.00	1.06 (0.96, 1.18)	1.18 (1.05, 1.33)	1.40 (1.19, 1.65)	0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	1.11 (1.00, 1.24)	1.18 (1.04, 1.33)	1.28 (1.07, 1.52)	0.0034
Coffee consumption excluding participants who never drink coffee					
	Men				
Number of cases/number of participants	670/2222	1521/5206	953/3142	335/972	
Age-adjusted OR (95% CI)	1.00	1.08 (0.96, 1.21)	1.25 (1.11, 1.42)	1.52 (1.29, 1.80)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	1.02 (0.91, 1.15)	1.12 (0.98, 1.27)	1.25 (1.05, 1.49)	0.0055
	Women				
Number of cases/number of participants	636/2079	1731/6041	939/3384	313/1025	
Age-adjusted OR (95% CI)	1.00	1.10 (0.98, 1.23)	1.23 (1.08, 1.39)	1.45 (1.22, 1.72)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	1.14 (1.01, 1.28)	1.21 (1.06, 1.39)	1.32 (1.10, 1.58)	0.0010
Coffee consumption with sugar or syrup excluding participants who never drink coffee					
	Men				
Number of cases/number of participants	403/1140	871/2463	464/1219	139/322	
Age-adjusted OR (95% CI)	1.00	1.12 (0.97, 1.31)	1.39 (1.16, 1.65)	1.70 (1.31, 2.20)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	1.04 (0.89, 1.22)	1.17 (0.97, 1.41)	1.31 (0.99, 1.72)	0.024
	Women				
Number of cases/number of participants	310/907	710/1940	279/804	98/222	
Age-adjusted OR (95% CI)	1.00	1.33 (1.12, 1.58)	1.42 (1.15, 1.75)	2.11 (1.54, 2.89)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	1.34 (1.11, 1.60)	1.35 (1.08, 1.69)	1.88 (1.35, 2.63)	0.0002
Coffee consumption without sugar or syrup excluding participants who never drink coffee					
	Men				
Number of cases/number of participants	267/1082	650/2743	489/1923	196/650	
Age-adjusted OR (95% CI)	1.00	1.06 (0.90, 1.26)	1.27 (1.06, 1.52)	1.63 (1.30, 2.04)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	1.02 (0.86, 1.22)	1.16 (0.97, 1.41)	1.35 (1.06, 1.72)	0.0041
	Women				
Number of cases/number of participants	326/1172	1021/4101	660/2580	215/803	
Age-adjusted OR (95% CI)	1.00	1.02 (0.88, 1.19)	1.23 (1.05, 1.45)	1.37 (1.11, 1.69)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	1.06 (0.90, 1.24)	1.22 (1.03, 1.45)	1.24 (0.99, 1.56)	0.0063

[a] The multivariate OR has been adjusted for age (40–44, 45–49, 50–54, 55–59, or 60–64 years), daily tooth brushing (<2, 2,or >2 times/day), years of education (<10, 10–12, or ≥13), body mass index (calculated as weight in kilograms divided by height in meters squared; <18.5, 18.5–22.9, 23.0–24.9, 25.0–29.9, or ≥30.0), time spent walking (<1 or ≥1 h/day), history of stroke, myocardial infarction, diabetes mellitus, and cancer (for each disease, yes or no), smoking status (never, former, currently smoking 1–19, or currently smoking ≥20 cigarettes/day), alcohol drinking (never, former, current), consumption of sweets such as *manju* (a steamed bean-jam bun), *yokan* (sweetened and jellied bean paste), or cake (<3 or ≥3 times/week), daily consumption of *miso* (soybean paste) soup, soybean products, milk (for each food, almost everyday or not), total fish (categorized into quartiles: <21.7, 21.7–47.5, 47.5–53.4, or ≥53.4 g/day for men; <22.8, 22.8–41.3, 41.3–53.4, or ≥53.4 g/day for women), green tea, oolong tea, and black tea (for each beverage, never or occasionally, 1–2, 3–4, or ≥5 cups/day) and total intake of calories (categorized into quartiles: <1265.8, 1265.8–1603.4, 1603.4–1933.2, or ≥1933.2 kcal/day for men; <1027.3, 1027.3–1242.8, 1242.8–1439.0, or ≥1439.0 kcal/day for women).

caries and periodontal disease. However, as these diseases represent an intermediate state leading to tooth loss, we consider that absence of information about them did not largely modify our results. Finally, since the response rate was not high (57.6%), the respondents might not have been a representative sample of the source population of Ohsaki City residents. The relatively low response rates should be kept in mind when interpreting the results.

Conclusions

The present findings indicate that green tea consumption is associated with decreased odds of tooth loss.

Conflict of interest statement
The authors declare that there are no conflicts of interest.

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Study Profile

The Ohsaki Cohort 2006 Study: Design of Study and Profile of Participants at Baseline

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ABSTRACT

Background: Large-scale cohort studies conducted in Japan do not always include psychosocial factors as exposures. In addition, such studies sometimes fail to satisfactorily evaluate disability status as an outcome.

Methods: This prospective cohort study comprised 49 603 (22 438 men and 27 165 women) community-dwelling adults aged 40 years or older who were included in the Residential Registry for Ohsaki City, Miyagi Prefecture, in northeastern Japan. The baseline survey, which included psychosocial factors, was conducted in December 2006. Follow-up of death, immigration, cause of death, cancer incidence, and long-term care insurance certification was started on 1 January 2007.

Results: The response rate was 64.2%. In general, lifestyle-related conditions in the study population were similar to those of the general Japanese population; however, the proportion of male current smokers was higher in the cohort. The association between age and the proportion of those reporting psychological distress showed a clear U-shaped curve, with a nadir at age 60 to 69 years in both men and women, although more women were affected by such distress than men. The proportion of those who reported a lack of social support was highest among those aged 40 to 49 years. Most men and women surveyed did not participate in community activities. Among participants aged 65 years or older, 10.9% of participants were certified beneficiaries of the long-term care insurance system at baseline.

Conclusions: The Ohsaki Cohort 2006 Study is a novel population-based prospective cohort study that focuses on psychosocial factors and long-term care insurance certification.

Key words: long-term care insurance; population-based; psychosocial factors; study design; the Ohsaki Cohort 2006 Study

INTRODUCTION

Increasing evidence suggests that, in addition to biomedical factors, a broad range of psychosocial factors influences general health.[1–3] However, large-scale cohort studies performed in Japan may not have sufficiently considered these factors as exposures in evaluating health outcomes.[4–9]

In addition to this tendency to overlook psychosocial exposures, some types of health outcomes, such as disability status, have not been satisfactorily examined in large-scale epidemiological studies in Japan.[4–9] Although there is growing concern about the quality of life of seniors,[10,11] assessment of quality of life—in particular disability status—by means of general population surveys presents many challenges.[12–14] In 2000, the Japanese government implemented a mandatory social long-term care insurance (LTCI) system to promote the independence of seniors by facilitating access to appropriate high-quality services of their choice, whenever and wherever needed.[15,16] Therefore, there is now an opportunity to use LTCI certification status as an alternative to the evaluation of physical and mental disability.

Based on the need for a novel cohort that accounts for the recent diversification in the abovementioned exposures and outcomes, we initiated a large population-based prospective cohort study, the Ohsaki Cohort 2006 Study, the main

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Table 1. Response rate and number of adults in source population, eligible population, and study population

	Aged 40–64 years		Aged ≥65 years		Total
	Men	Women	Men	Women	
No. of source population	23 647	22 760	12 750	18 944	78 101
No. of eligible population (A)	23 359	22 639	12 606	18 631	77 235
No. of persons responding to the survey	12 967	13 849	9690	13 704	50 210
No. of study population (B)	12 833	13 679	9605	13 486	49 603
Response rate (B/A) (%)	54.9	60.4	76.2	72.4	64.2

objective of which is to examine the association between psychosocial factors and both physical and mental disability status. Here, we report the design of the study and the profile of participants at baseline.

METHODS

Study design, setting, and participants

In this prospective cohort study, the source population for the baseline survey comprised community-dwelling individuals aged 40 years or older who were included in the Residential Registry for Ohsaki City, Miyagi Prefecture, northeastern Japan, as of 1 December 2006. The Residential Registry identified 78 101 persons (36 397 men; 41 704 women) in the area.

The baseline survey was conducted from 1 December to 15 December 2006. A questionnaire was distributed by the heads of individual administrative districts to individual households, after which it was collected by mail.

Baseline survey

The baseline questionnaire for persons aged 40 to 64 years requested information on the following, in sequence: (1) history of diseases, (2) family history of diseases, (3) health status over the last year, (4) smoking status, (5) alcohol drinking status, (6) dietary habits,[17] (7) job status and educational status, (8) present and past body weight and height, (9) general health status, (10) sports and exercise,[18,19] (11) psychological distress (using the K6, a 6-item instrument that assesses nonspecific psychological distress developed by Kessler and colleagues),[20–23] (12) social support,[24] (13) participation in community activities, (14) dental status, and (15) reproductive factors (in women).

Question items for persons aged 65 years or older were the same as those for persons aged 40–64, excluding family history of diseases, job status and educational status, present and past body weight and height, and reproductive factors. In addition, we included a frailty checklist (the Kihon Checklist, in Japanese),[25] along with (1) past body weight and height, (2) pain, and (3) daily activities. The Kihon Checklist is a tool developed by the Japanese Ministry of Health, Labour, and Welfare to screen for frailty, and is designed to measure actual task performance.[25]

All people who supplied their name and address, and completed most of the questionnaire, were regarded as eligible; all others were excluded. The reasonableness of data was evaluated according to predetermined rules.

Follow-up

We conducted this prospective cohort study with the cooperation of the Ohsaki City municipal government after obtaining their written agreement. The aim is to follow the cohort participants for mortality and immigration using the Residential Registry of Ohsaki City. We also confirm information regarding LTCI certification status among individuals aged 65 years or older, after obtaining written consent for review of these data. Causes of death are confirmed by review of death certificates, with approval from the Japanese Ministry of Internal Affairs and Communications and the Japanese Ministry of Health, Labour, and Welfare. Cancer incidence is also confirmed by review of data from the Miyagi Prefectural Cancer Registry, with approval from the Miyagi Prefectural Cancer Registry Committee.

Ethical issues

The return of questionnaires completed by the participants was regarded as consent to participate in the study, which involves cross-sectional analysis of baseline survey data and information on subsequent mortality and immigration. We provided an explanatory note on the questionnaire that stated we would follow the cohort participants for mortality and cancer incidence. The study protocol was reviewed and approved by the Ethics Committee of Tohoku University Graduate School of Medicine.

RESULTS

Data on the source population, eligible population, study population, and response rate by age and sex are shown in Table 1. Of the 78 101 people in the source population, we were unable to contact 866, yielding an eligible population of 77 235. Baseline questionnaires were collected from 50 210 persons, and valid responses were received from 49 603 (22 438 men and 27 165 women), who formed the study population of cohort participants. Among the invalid responses, 252 persons aged 65 years or older completed

Table 2. Selected baseline medical and lifestyle-related profiles of study population, by sex and age category

Variables	Age category (years)									
	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	≥85
Men										
No. of participants	1857	2365	2884	3427	2300	2477	2846	2391	1256	635
History of serious disease (%)										
Hypertension	7.7	14.6	18.8	25.4	32.7	37.8	41.9	44.0	39.7	35.3
Diabetes mellitus	3.6	5.2	7.5	11.0	12.8	14.4	16.2	13.6	11.5	10.1
Stroke	0.4	0.6	1.3	2.0	3.4	4.4	5.6	7.1	7.9	8.8
Myocardial infarction	0.1	0.7	1.0	1.8	3.5	4.7	5.9	8.5	9.7	11.5
Cancer	0.8	1.5	2.1	2.8	5.0	7.4	10.4	13.0	12.3	9.8
Current smokers (%)	59.5	56.7	50.6	46.8	40.4	31.4	25.9	21.3	19.2	11.1
Current alcohol drinkers (%)	81.5	80.6	80.7	79.2	77.0	69.1	61.6	53.2	45.3	30.3
Body mass index (%)										
<18.5 kg/m^2	2.7	2.5	1.7	2.0	2.5	3.0	3.7	6.2	11.0	10.9
≥25.0 kg/m^2	35.1	33.8	34.7	34.7	30.8	32.1	29.1	26.3	19.7	16.6
Time spent walking <1 hr/day (%)	69.4	68.4	67.5	67.2	67.3	63.9	67.9	74.2	79.0	85.3
Women										
No. of participants	1935	2488	3025	3638	2593	3070	3623	3303	2021	1469
History of serious disease (%)										
Hypertension	3.3	8.3	15.0	23.5	30.1	37.0	43.0	46.4	47.7	46.1
Diabetes mellitus	0.8	2.6	3.3	6.0	8.4	8.5	10.4	11.6	12.0	10.2
Stroke	0.3	0.2	0.6	0.5	1.1	1.6	2.5	3.8	4.6	6.3
Myocardial infarction	0.1	0.0	0.2	0.5	1.0	1.5	2.9	4.4	6.1	7.2
Cancer	2.0	2.7	4.3	4.7	6.9	6.0	5.9	6.2	6.9	7.9
Current smokers (%)	19.6	15.2	11.0	9.1	7.3	4.7	3.8	2.8	2.5	2.1
Current alcohol drinkers (%)	56.7	49.5	40.3	34.1	29.9	20.7	14.4	11.6	10.8	9.2
Body mass index (%)										
<18.5 kg/m^2	7.5	6.3	4.8	4.2	3.3	3.7	4.8	6.4	9.1	16.1
≥25.0 kg/m^2	20.1	22.6	27.4	28.3	32.2	34.9	35.2	31.9	27.7	22.0
Time spent walking <1 hr/day (%)	74.0	70.3	70.2	71.6	73.4	70.0	72.5	78.8	84.4	91.6

the questionnaires intended for those aged 40 to 64 years. Among the study population, 26 512 persons (53.4%) were aged 40 to 64 years, and 23 091 (46.6%) were aged 65 years or older. The response rate was calculated by dividing the study population by the total eligible population, yielding 64.2%. The response rate for men was 62.4% (22 438/35 965), and was somewhat lower than that for women, at 65.8% (27 165/41 270). By age, the response rate for persons aged 65 years or older was high, at 73.9% (23 091/31 237), while that for persons aged 40 to 64 years was 57.6% (26 512/45 998).

Selected baseline medical and lifestyle-related profiles of the study population

The selected baseline medical and lifestyle-related profiles of the study population are shown in Table 2. The prevalence of a history of serious disease rose with increasing age in both men and women. In men, the distributions of a history of hypertension, diabetes mellitus, and cancer all peaked at age 70 to 79 years. More than 40% of men aged 75 to 79 years had a history of hypertension. About 60% of men, and 20% of women, aged 40 to 44 years currently smoked, and more than 80% of men, and 50% of women, in the same age group currently drank alcohol at baseline, which decreased with increasing age. The proportion of obese individuals, defined as a BMI ≥25.0 kg/m^2, was inversely associated with age in men, but weakly positively associated with age in women, with a peak at age 70 to 79 years. The association between age and the proportion of individuals who were underweight, defined as a BMI <18.5 kg/m^2, was J-shaped for men and U-shaped for women. The association between age and the proportion of those who spent less than 1 hour per day walking was J-shaped for both men and women.

Selected baseline psychosocial profiles of the study population

With regard to psychosocial profiles (Table 3), the association between age and the proportion of participants who had psychological distress showed a clear U-shaped curve in both sexes, with a nadir in those aged 60 to 69 years; psychological distress was more common in women than in men. The proportion of those who reported lack of social support was highest among those in their 40s, and decreased with age for every component of social support in both men and women. More men than women reported lack of social support. About 20% of men in their 40s reported lack of social support for consultation when in trouble. In contrast, the association between age and the proportion of those who did not participate in community activities showed a J-shape curve with a nadir at age 60 to 69 years.

Table 3. Selected baseline psychosocial profiles of study population, by sex and age category

Variables	Age category (years)									
	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	≥85
Men										
Psychological distress[a], yes (%)	7.1	7.4	6.2	5.1	4.7	4.1	4.8	5.7	7.0	6.9
Lack of social support (%)										
(i) To consult when you are in trouble	19.0	20.1	18.0	18.0	18.1	14.5	12.7	13.3	13.1	13.7
(ii) To consult when you are in bad physical condition	15.8	15.7	15.1	13.9	12.6	8.9	8.0	7.7	5.9	7.4
(iii) To help with your daily housework	18.2	18.9	17.8	17.5	18.8	17.6	15.8	16.2	13.0	9.0
(iv) To take you to a hospital	13.5	12.3	11.7	9.5	9.5	7.8	7.6	8.0	6.9	5.3
(v) To take care of you	10.8	11.0	11.6	9.6	10.5	8.8	9.1	9.0	9.9	8.9
No participation in community activities (%)										
(i) Neighborhood association activities	50.1	46.0	45.8	44.6	45.5	42.9	48.0	50.2	59.5	70.6
(ii) Sports or exercise	47.9	49.6	51.6	53.9	49.5	45.8	50.3	55.4	61.7	70.9
(iii) Volunteering	69.3	63.6	61.4	60.4	60.5	56.1	60.8	65.1	75.6	88.7
(iv) Social gatherings	52.7	53.0	50.8	48.5	46.3	40.3	44.9	50.7	61.0	78.9
Women										
Psychological distress[a], yes (%)	9.9	8.7	7.4	6.6	5.4	5.3	6.4	7.5	10.5	13.9
Lack of social support (%)										
(i) To consult when you are in trouble	11.1	10.8	10.2	10.5	9.9	7.9	7.4	7.1	7.7	4.9
(ii) To consult when you are in bad physical condition	11.5	10.8	9.2	9.1	8.9	6.3	5.8	5.1	4.8	2.7
(iii) To help with your daily housework	16.5	15.4	13.5	16.2	16.8	15.3	15.7	13.0	9.7	4.5
(iv) To take you to a hospital	13.3	11.6	7.5	8.8	8.2	8.0	7.8	7.4	5.5	3.4
(v) To take care of you	16.5	15.6	13.4	16.4	17.3	17.8	19.0	17.1	12.9	7.0
No participation in community activities (%)										
(i) Neighborhood association activities	42.3	52.0	57.3	56.3	54.2	53.7	55.8	59.5	69.8	86.8
(ii) Sports or exercise	61.1	58.8	60.5	56.4	51.4	50.0	54.1	62.5	75.0	88.3
(iii) Volunteering	78.8	75.7	73.7	70.1	67.3	67.0	74.3	81.0	88.9	97.4
(iv) Social gatherings	59.5	59.7	60.3	56.9	53.2	51.1	56.2	61.0	74.0	91.9

[a]The K6 was used as an indicator of psychological distress.[20–23]

Table 4. Number (%) of participants certified in the long-term care insurance system of Japan at baseline

Care level	Age category (years)				
	65–69	70–74	75–79	80–84	≥85
Men					
Uncertified	1817 (97.6)	2037 (95.5)	1683 (92.6)	808 (85.0)	316 (65.8)
Support level 1[a]	4 (0.2)	7 (0.3)	13 (0.7)	14 (1.5)	12 (2.5)
Support level 2[a]	4 (0.2)	17 (0.8)	16 (0.9)	22 (2.3)	11 (2.3)
Care level 1[b]	10 (0.5)	21 (1.0)	27 (1.5)	23 (2.4)	47 (9.8)
Care level 2[b]	15 (0.8)	11 (0.5)	25 (1.4)	34 (3.6)	30 (6.3)
Care level 3[b]	3 (0.2)	15 (0.7)	20 (1.1)	28 (2.9)	27 (5.6)
Care level 4[b]	5 (0.3)	18 (0.8)	25 (1.4)	11 (1.2)	18 (3.8)
Care level 5[b]	4 (0.2)	6 (0.3)	9 (0.5)	11 (1.2)	19 (4.0)
Women					
Uncertified	2153 (98.3)	2411 (95.0)	2076 (90.2)	1090 (77.2)	520 (49.4)
Support level 1[a]	4 (0.2)	24 (0.9)	41 (1.8)	49 (3.5)	36 (3.4)
Support level 2[a]	7 (0.3)	31 (1.2)	45 (2.0)	52 (3.7)	59 (5.6)
Care level 1[b]	9 (0.4)	25 (1.0)	57 (2.5)	92 (6.5)	126 (12.0)
Care level 2[b]	3 (0.1)	13 (0.5)	26 (1.1)	48 (3.4)	93 (8.8)
Care level 3[b]	8 (0.4)	10 (0.4)	20 (0.9)	28 (2.0)	83 (7.9)
Care level 4[b]	5 (0.2)	15 (0.6)	22 (1.0)	29 (2.1)	70 (6.7)
Care level 5[b]	2 (0.1)	10 (0.4)	15 (0.7)	24 (1.7)	65 (6.2)

[a]Those who require support for daily activities; a higher number indicates a need for greater support.
[b]Those who require continuous care; a higher number indicates a need for greater continuous care.

LTCI certification at baseline

The percentages of participants aged 65 years or older at baseline who received LTCI certification are shown in Table 4. Among participants in this age group, 16 739 (72.5%) provided written consent for our review of the information. Among these seniors, 10.9% had been LTCI-certified as of 15 December 2006. The proportion of those who were LTCI-certified increased linearly in relation to age

category in both men and women; more women were LTCI-certified than men. Among participants aged 85 years or older, about 34% of men and 51% of women were LTCI-certified.

DISCUSSION

To characterize the study population, we compared selected health-related characteristics of the population with those of the Japanese general population, by sex and age, using data from The National Health and Nutrition Survey in Japan, 2005.[26] Among men, the proportion of current smokers was higher in the study population than in the general population. The proportions of current smokers at baseline in the present cohort population by age category were 56.7% to 59.5%, 46.8% to 50.6%, 31.4% to 40.4%, and 21.3% to 25.9% for men in their 40s, 50s, 60s, and 70s, respectively (Table 2); the corresponding figures from the national survey were 44.1%, 42.5%, 34.0%, and 20.0% (≥70 years). In contrast, smoking status among women in the study population was very similar to that in the general population. Other variables, including obesity, underweight, history of serious diseases, alcohol drinking, and time spent walking, were similarly prevalent among middle-aged and elderly men and women in the study population and general population. To take one example, the proportions of men who were obese (BMI of ≥25.0) at baseline in the present cohort population by age category were 33.8% to 35.1%, 34.7%, 30.8% to 32.1%, and 26.3% to 29.1% for those in their 40s, 50s, 60s, and 70s, respectively (Table 2); the corresponding figures from the national survey were 34.1%, 31.4%, 30.7%, and 26.0% (≥70 years), respectively.

We also compared the LTCI certification status of the participants with that of the Japanese population by sex and age.[27] The proportions of those certified at baseline in the present cohort population, by age category, were 2.4%, 4.5%, 7.4%, 15.0%, and 34.2% for men aged 65–69, 70–74, 75–79, 80–84, and ≥85 years (Table 4); the corresponding figures from the estimated national survey were 3.0%, 6.2%, 11.9%, 22.1%, and 45.0%, respectively.[27] The same comparison among women yielded similar results, with smaller proportions in the present cohort population. These observed smaller proportions were not unexpected, because people with disabilities have more difficulties in responding to questionnaires. However, the small magnitude of the difference indicates that the selection bias was not serious.

Our study had some limitations. First, the response rate (64.2%) was not very high. The response rates of men and women aged 40 to 64 years were lower (54.9% and 60.4%, respectively) than those of men and women aged 65 years or older (76.2% and 72.4%, respectively). These relatively low response rates, especially among participants aged 40 to 64 years, should be kept in mind when interpreting the study results. Second, among the psychosocial variables studied, the items regarding job status and educational status, social support, and participation in community activities have not been adequately validated. Third, LTCI certification does not directly indicate an individual's disability status; however, it does reflect the burden of disability on society.[15,16]

We have already conducted a prospective cohort study in the catchment area of Ohsaki Public Health Center. This study began in 1995 and was named the Ohsaki National Health Insurance (NHI) beneficiary's Cohort Study, or the Ohsaki Cohort Study.[5] The primary purpose of that study was to demonstrate quantitatively the economic impact of health-related lifestyles; the Ohsaki Cohort 2006 Study, in contrast, does not assess medical costs. The catchment area of the Ohsaki Public Health Center included Furukawa City, and the towns of Nakaniida, Onoda, Miyazaki, Shikama, Matsuyama, Sanbongi, Kashimadai, Iwadeyama, Naruko, Wakuya, Tajiri, Kogota, and Nango. Among these areas, the city of Furukawa, and the towns of Matsuyama, Sanbongi, Kashimadai, Iwadeyama, Naruko, and Tajiri were consolidated to form the city of Ohsaki on 31 March 2006. The population of the present study and that investigated in the Ohsaki Cohort overlap by about one-third.

In conclusion, we have begun a large population-based prospective study that focuses on psychosocial factors and LTCI certification status. The psychological factors include measurements of job status and educational status, psychological distress,[20–23] social support,[24] participation in community activities, and the Kihon Checklist.[25] LCTI certification is followed up as an alternative to individual disability status, and as a measure of the economic burden of disability on society.

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Impact of Nocturia on Bone Fracture and Mortality in Older Individuals: A Japanese Longitudinal Cohort Study

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Purpose: We evaluated the association of nocturia with fracture and death in a large, community based sample of Japanese individuals 70 years old or older.

Materials and Methods: The baseline in this population based study was determined in 2003 by an extensive health interview with each participant. In this study we followed 784 individuals with a mean ± SD age of 76.0 ± 4.6 years (range 70 to 97). Information on mortality and fracture during the study period was provided by the National Health Insurance system and details on fractures were collected from medical records. We compared the risk of bone fracture and death with or without nocturia in a multivariate Cox proportional hazard model.

Results: Nocturia (2 or greater voids per night) was present in 359 of the 784 participants (45.7%). Fracture was observed in 41 cases, including 32 fall related cases. For all fractures and fall related fractures with nocturia the HR was 2.01 (95% CI 1.04–3.87) and 2.20 (95% CI 1.04–4.68, each p = 0.04). Death occurred in 53 cases. The mortality rate in individuals with nocturia was significantly higher than in those without nocturia. For mortality in patients with nocturia the age-gender adjusted HR was 1.91 (95% CI 1.07–3.43, p = 0.03). Even when further adjusted for diabetes, smoking status, history of coronary disease, renal disease and stroke, tranquilizers, hypnotics and diuretics, the positive relationship was unchanged (HR 1.98, 95% CI 1.09–3.59, p = 0.03).

Conclusions: During a 5-year observation period elderly individuals with nocturia were at greater risk for fracture and death than those without nocturia.

Key Words: urinary bladder; nocturia; fractures, bone; mortality; aged

Abbreviations and Acronyms

BMI = body mass index
NHI = National Health Insurance
QOL = quality of life
SWS = slow wave sleep

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NOCTURIA is defined by the International Continence Society as the complaint that the individual awakens at night 1 or more times to void.[1] The prevalence of nocturia increases with age, such that around 70% of individuals 55 years old or older void at least once per night.[2] Despite or perhaps due to this high prevalence in society nocturia is frequently dismissed as an inevitable consequence of aging and, thus, it remains untreated in many individuals.[3]

Nocturia is the leading cause of sleep fragmentation in older adults.[3] Due to its chronic impact on the sleep cycle it can have serious consequences for daytime function, mood, QOL and health.[4–7] The average first nocturia episode occurs within 2 to 3 hours of going to bed. Awakening at this time is likely to interrupt SWS, which is the deep sleep phase believed to be most restorative.[8] Interrupting SWS is associated with a number of nega-

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tive sequelae, including impaired normal glucose homeostasis.[9] Those with nocturia report significantly worse QOL and health than those without nocturia.[2,7,10,11]

Particularly in older individuals falls are a major health problem and the principal cause of death from injury in this group.[12] Previous studies suggest that nocturia may be an important risk factor for falls in men older than 65 years.[13] In a community based study the risk of falling was more than doubled in participants with at least 3 episodes of nocturia per night.[12] Others determined that the risk of hip fracture is independently increased by increased nocturnal micturition and nocturnal urine output.[14] Hip fracture in the elderly population and bone fracture in general may lead to severe complications and in some cases death. For example, there is an overall 5.3% in-hospital mortality rate after hip fracture.[14]

Nocturia is associated with a greater risk of mortality.[15] The increased risk of fracture with nocturia may be a mechanism by which the mortality risk increases. Also, nocturia is associated with several comorbidities, such as diabetes and coronary disease. Thus, the increased mortality rate in individuals with nocturia may be at least partially attributable to the increased incidence of those health issues. However, in a study of patients with coronary disease nocturia was a significant independent predictor of mortality.[16] We evaluated the association of nocturia with fracture and death in a large Japanese, community based sample of individuals 70 years old or older.[17–20]

MATERIALS AND METHODS

Study Participants

The Tsurugaya Project was a community based, comprehensive geriatric assessment that recruited individuals ages 70 years old or older who lived in the Tsurugaya area of Sendai, a major city in the Tohoku area of Japan. At the time of the study (July to August 2003) 2,925 individuals 70 years old or older lived in Tsurugaya. All were invited to participate in the assessment, which included medical status, physical function, cognitive function and dental status. Of those invited 948 individuals attended the assessment and provided informed consent for data analysis, of whom 784 who had joined the NHI system and agreed to a medical record review were included in this study. The study protocol was approved by the Tohoku University Graduate School of Medicine ethics committee.

Data

Collection. Information on nocturia was collected by trained interviewers. They asked participants, "During the last month how many times did you most typically get up to urinate from the time you went to bed at night until the time you got up in the morning?" Those who reported voiding 2 or greater times per night were defined as having nocturia since previous studies showed that individuals with 2 or more voids per night have significantly worse QOL and health than those without nocturia.[2,7,10,11]

Information on smoking status, drinking status, medication and disease history was obtained via questionnaire. The drug information was confirmed by a qualified pharmacist.[20] To evaluate the ability of participants to maintain balance we measured functional reach.[21,22] This test measures how far a participant can reach forward beyond arm length and maintain a fixed base of support while standing without losing balance. We attempted the test twice. The longer reach result was used in analysis.

Followup. We prospectively collected data on medical care, expenditures and mortality in all individuals in the cohort study from August 2003 to March 2008. We obtained NHI claims history files from the Miyagi NHI Association. The files included the number of outpatient visits and days of inpatient care, charges for outpatient and inpatient care, and mortality data. When a beneficiary was withdrawn from the NHI, the date and reason were coded on a NHI withdrawal history file. This file identified survival and emigration status in each participant. NHI claims and withdrawal history files were linked with our baseline survey data file based on the beneficiary identification number. The incidence and causes of fracture were investigated using the NHI claim record and patient hospital records. NHI records were used to identify the hospital where patients were admitted. We then visited the hospital and reviewed hospital records to confirm the diagnosis, incident day and reason for fracture.

Statistical Analysis

We assessed the relationship of baseline characteristics with demographic variables and the nocturia risk using the t and chi-square tests, and multivariate logistic regression analysis. Variables under consideration were gender, age, high blood glucose, history of coronary disease, nephropathy, diabetes, malignant disease and smoking status. We compared the fracture risk with or without nocturia using the multivariate Cox proportional hazard model adjusted for age, gender, BMI, tranquilizers, hypnotics, diuretics and functional reach. Differences in mortality with time according to the presence or absence of nocturia were assessed by Kaplan-Meier curves and statistical significance was calculated with the log rank test. We compared the risk of mortality with or without nocturia using an age-gender adjusted Cox proportional hazard model. We also used a model adjusting for age, gender, BMI, diabetes, smoking status, history of coronary disease, renal disease and malignant disease, tranquilizers, hypnotics and diuretics. Statistically significant differences were considered at $p < 0.05$. SAS®, version 9.1 was used for analyses.

RESULTS

Of the 784 participants 427 (54.5%) were female. Overall mean ± SD age was 76.0 ± 4.6 years (range 70 to 97). In those without and with nocturia mean age was 75.2 ± 4.2 and 77.0 ± 4.8 years (OR 1.9, 95% CI 1.05–1.13, $p < 0.01$), and mean BMI was

24.1 ± 3.2 and 24.1 ± 3.5 kg/m^2 (HR 1.02, 95% CI 0.97–1.06, p = 0.82), respectively.

Nocturia

Nocturia (2 or greater voids per night) was present in 359 of 784 cases (45.8%). Table 1 shows the results of multivariate analysis of the effect of demographic and baseline variables on nocturia prevalence. Male gender, older age, coronary disease history and malignant disease were associated with a significantly increased risk of nocturia. Current smoking was associated with a significantly decreased risk of nocturia.

Fracture

We noted fracture in 41 cases, of which 32 were fall related. Eight, 6 and 21 patients had fracture of the arm, lower limb and hip, respectively. Six fractures were classified as other.

The cumulative incidence rate of fracture was significantly higher in individuals with vs without nocturia (26 of 359 or 7.2% vs 15 of 425 or 3.5%, fig. 1). Similarly the cumulative incidence rate of fall related fracture was significantly higher in those with vs without nocturia (21 of 359 or 5.8% vs 11 of 425 or 2.6%). Multivariate HR adjusted for age, BMI, tranquilizers, hypnotics, diuretics and functional reach in all fractures in men, women and all participants with nocturia was 2.61 (95% CI 0.76–8.95, p = 0.13), 2.07 (95% CI 0.95–4.51, p = 0.07) and 2.01 (95% CI 1.04–3.87, p = 0.04), respectively (table 2). The HR for fall related fracture in all participants was 2.20 (95% CI 1.04–4.68, p = 0.04).

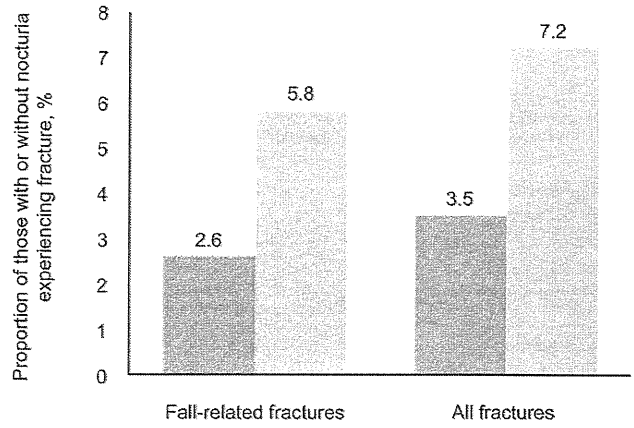

Figure 1. Incidence of all and fall related fractures in 359 patients with (light blue bars) and in 425 without (dark blue bars) nocturia was significantly higher in former (each p = 0.03).

Mortality

The cumulative mortality rate was higher in individuals with than without nocturia (35 of 359 or 9.7% vs 18 of 425 or 4.2%). Figure 2 shows Kaplan-

Table 1. *Baseline characteristics by nocturia status*

	No. No Nocturia (%)	No. Nocturia (%)	p Value (t or chi-square test)	OR (95% CI)
Gender:			0.02	
M	177 (41.7)	180 (50.1)		Referent
F	248 (58.4)	179 (49.9)		0.64 (0.42–0.99)
High blood glucose:			0.2	
No	337 (79.3)	271 (75.5)		Referent
Yes	88 (20.7)	88 (24.5)		1.14 (0.80–1.63)
Tranquilizers:			0.32	
No	378 (88.9)	311 (86.6)		Referent
Yes	47 (11.1)	48 (13.4)		1.14 (0.80–1.63)
Hypnotics:			0.45	
No	389 (91.5)	323 (90.0)		Referent
Yes	36 (8.5)	36 (10.0)		1.37 (0.87–2.15)
Diuretics:			0.18	
No	405 (95.3)	334 (93.0)		Referent
Yes	20 (4.7)	25 (7.0)		1.19 (0.63–2.27)
Renal disease history:			0.47	
No	396 (93.2)	339 (94.4)		Referent
Yes	29 (6.8)	20 (5.6)		0.71 (0.38–1.32)
Myocardial infarction history:			<0.01	
No	394 (92.7)	308 (85.8)		Referent
Yes	31 (7.3)	51 (14.2)		1.87 (1.14–3.08)
Malignant disease history:			<0.01	
No	396 (93.2)	311 (86.6)		Referent
Yes	29 (6.8)	48 (13.4)		2.15 (1.30–3.57)
Smoking status:				
Never	258 (60.7)	196 (54.6)	0.02	Referent
Past	112 (26.4)	129 (35.9)		1.08 (0.69–1.69)
Current	48 (11.3)	27 (7.5)		0.59 (0.32–1.08)

Table 2. *All fracture and all cause mortality by nocturia status*

	No. Nighttime Voids		
	1 or Less	2 or Greater	p Value
	*All fracture**		
Men:	174	178	
No. fracture	4	9	
HR (95% CI)	1.00	2.61 (0.76–8.95)	0.13
Women:	237	162	
No. fracture	11	17	
HR (95% CI)	1.00	2.07 (0.95–4.51)	0.07
Overall:	425	359	
No. fracture	15	26	
HR (95% CI)	1.00	2.01 (1.04–3.87)	0.04
	All cause mortality†		
No. deaths	18	35	
HR (95% CI):			
Crude model	1.00	2.43 (1.38–4.30)	<0.01
Model 2†	1.00	1.91 (1.07–3.43)	0.03
Model 3‡	1.00	1.98 (1.09–3.59)	0.02

* Adjusted for age, gender, BMI, tranquilizers, hypnotics, diuretics and functional reach.

† Adjusted for age, gender and BMI.

‡ Adjusted for model 2 plus diabetes, smoking status, coronary disease, renal disease, stroke, tranquilizers, hypnotics and diuretics.

Meier mortality curves. There was a significant difference between individuals with and without nocturia (p = 0.0015).

The age-gender adjusted HR for death in patients with 2 or greater episodes of nocturia per night was 1.91 (95% CI 1.07–3.43, p = 0.03). In the additional, more comprehensive model adjusting for age, gender, BMI, diabetes, smoking status, history of coronary disease, renal disease and stroke, tranquilizers, hypnotics and diuretics nocturia still independently predicted increased mortality risk (HR 1.98, 95% CI 1.09–3.59; p = 0.03, table 2).

DISCUSSION

In this 5-year study we considered potential risk factors for nocturia and the subsequent effect of nocturia on the incidence of fracture and death in individuals 70 years old or older. Key findings were that nocturia (2 or greater voids per night) was present in almost half of the population and it was an independent risk factor for fracture and for increased mortality.

In a previous 5-year study nocturia was identified as an independent risk factor for hip fracture.[23] Consistent with this finding we found that the fracture prevalence more than doubled in patients with nocturia. Generally women are much more likely to have osteoporosis than men, which significantly increases the risk of fracture.[24] Also, the physiology of nocturia differs between men and women because of the prostate. However, there is same tendency that nocturia correlates with fracture in men only (p = 0.13) and in women only (p = 0.07). When considering fracture of any cause, all participants (men and women) with nocturia were at increased risk on multivariate adjusted analysis.

The correlation between the number of nighttime voids and the fracture prevalence was not a linear proportional correlation (data not shown). This may have been due to the multifactorial etiology of fracture and the relatively small number of events. On the other hand, falls are a major health problem in older people in general[25] and nocturia seems to be an important additional contributor to the fracture risk in this age group. Since details on time of day were not available, it was not possible to ascertain whether injuries were sustained during the night and as a direct result of nighttime visits to the toilet. Patients with nocturia may be more at risk for daytime injury due to the fragmented sleep and fatigue caused by nocturnal voiding. Fractures of any cause have a major impact on QOL. Thus, any lifestyle modifications or treatments that decrease nocturia episodes and so decrease the incidence of falls and subsequent fracture would be beneficial in terms of decreasing the economic and personal burdens involved.

We also found an increased risk of death in elderly patients with nocturia. Nocturia can arise from many physiological conditions. Thus, the possibility exists that the causes of the increased nocturia rate also caused the increased mortality rate. However, on analysis adjusted for a wide range of medical conditions and demographic variables nocturia was an independent predictor of death. This suggests an alternative underlying mechanism that

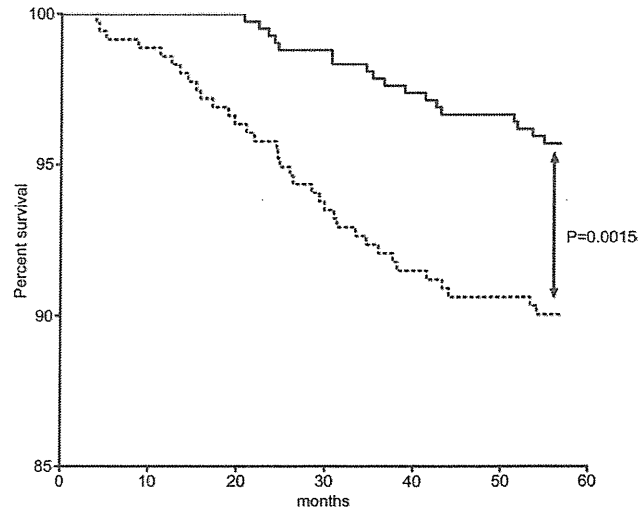

Figure 2. Kaplan-Meier estimates show significantly lower mortality in patients without (solid curve) than with (dotted curve) nocturia (log rank test p = 0.0015), defined as 1 or fewer vs 2 or greater voids per night, respectively.

may be directly related to nocturia, and increased fracture and/or the fragmented sleep caused by the need to wake to void repeatedly at night. Poor sleep is associated with poor health and SWS interruption has an effect on the regulation of physiological processes, such as glucose metabolism[9] and immunity.[26] Thus, nocturia may increase the risk of death by its impact on sleep and subsequent health implications.

In the elderly population those with nocturia appear to be at increased risk for fracture and death regardless of a range of possible comorbid conditions. Thus, nocturia may be a marker of more serious underlying conditions in some patients as well as a carrier of additional risk in terms of 1) injury possibly directly related to nighttime visits to the toilet and 2) an independent relationship with increased mortality possibly mediated by the increase in injuries and/or the effects of poor sleep on health.

Regardless of the true mechanisms of the relationship of nocturia with fracture and death the existence of an association between the condition and serious consequences in the patient is clear. Thus, this should not be considered a trivial and/or inevitable consequence of aging. Rather, nocturia deserves thorough evaluation of the underlying causes in each patient. Clinicians should actively monitor nocturia in older patients and consider whether those complaining of insomnia may in fact experience sleep disturbance due to nighttime voiding. After the specific etiology of nocturia is established in each individual appropriate treatment targeting the relevant contributing factors should be offered to minimize the repercussions of the condition and any possible underlying factors for patient health and overall QOL.[11]

Treatment for nocturia is available.[27] It has the potential to decrease these risks in patients with nocturia by decreasing the number of voids per night, decreasing fragmentation of the sleep cycle and increasing the potential for uninterrupted SWS. Treatment selection should be based on the etiology of the condition in each patient. As discussed, there are many possible contributors to nocturia but nocturnal polyuria is present in up to about 83% of patients[28,29] and is especially common in the elderly population. This is believed to be related to decreased secretion of antidiuretic hormone with age.[30] Further studies of the impact of treatment to effectively decrease the frequency of nocturia on the fracture and mortality rates would be of interest and extend the current evidence base supporting the benefits of treatment for this condition. In conclusion, in this 5-year cohort study in an elderly, community dwelling population in Japan those with nocturia (2 or greater voids per night) were at increased risk for fracture and increased risk for death even when multivariate analysis was adjusted for several possible contributing comorbidities and lifestyle factors.

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ORIGINAL ARTICLE

Impact of physical activity and performance on medical care costs among the Japanese elderly

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Aim: Physical activity (PA) is known to be inversely associated with medical care costs. The amount of PA is strongly associated with the level of physical performance among the elderly population. Therefore, it is possible that known relation between PA and medical care merely shows the relation between physical performance and medical care. To know whether PA itself relates to medical care, considering physical performance is necessary. The aim of this study was to ascertain the impact of PA on medical care expenditure by considering the physical performance in an elderly community-dwelling population.

Methods: We investigated 483 subjects who did not have any history of diseases relating to limited PA and who completed both a self-administered questionnaire including questions on PA and underwent a physical performance measurement. We ascertained the total medical care costs through a computerized linkage with claims lodged between August 2002 and March 2008 with the Miyagi National Health Insurance Association.

Results: The physical performance was positively associated with their level of PA. After multivariate adjustment for covariables including the levels of physical performance, the per capita medical care costs were found to be $US 827.3 (598.0–1056.7) (mean, 95% confidence interval), $US 711.1 (476.4–945.8) and $US 702.0 (461.6–942.4) (*P* for linear trend = 0.02) per month for those who had the lowest, average and the highest level of PA, respectively.

Conclusion: This prospective study indicates that a higher level of PA is associated with lower medical care costs among the Japanese elderly irrespective of physical performance. **Geriatr Gerontol Int 2010; 10: ••–••.**

Keywords: community-dwelling elderly population, medical care costs, physical activity, physical performance.

Introduction

The rising medical care costs associated with the growth of the elderly population is an ongoing problem worldwide.[1,2] In the 2005 Japanese census report, the proportion of the elderly population in the total population of the country was 20.1%. This proportion is expected to

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reach 35.7% by 2050.[3] In the 2002 Health and Welfare Statistics Association survey, 50.4% of the total national medical care costs were incurred by elderly individuals over 65 years of age.[4] According to the survey, the average per capita monthly medical care costs were $US 1284 for the under-65 age group and $US 5536 for the over-65 age group; that is, the costs for the latter group were five times higher than those for the former.

A sedentary lifestyle has been found to be associated with an increased risk of developing various chronic diseases and mortality.[5–8] Actually, several studies have reported that physical activity (PA) is inversely associated with medical care costs.[9–11] The promotion of regular PA may lead to a reduction in medical care costs. The amount of PA, however, is strongly associated with the level of physical performance, especially in the elderly population.[12–17] Therefore, it is natural to assume that physical performance would be an important mediator in the relationship between PA and medical care costs. Thus, careful consideration of this potentially important confounding or effect-modifying factor is needed when analyzing the data. However, to our knowledge, no previous studies have investigated the impact of physical activity on medical care expenditure using stratified analyses of physical performance levels.

We thus designed a cohort study of National Health Insurance (NHI) beneficiaries to investigate the link between PA levels and medical care costs in association with physical performance in an elderly Japanese community-dwelling population.

Methods

Study participants

Our data were derived from a prospective observation of NHI beneficiaries in suburban Japan through August 2002 to March 2008. In 2002, there were 2730 individuals aged 70 years and older living in Tsurugaya, a residential area in one of the major cities in northern Japan, Sendai City. We invited all of these individuals to participate in a comprehensive geriatric assessment[18] in which the physical, mental and social functioning of elderly people was examined to assess the early deterioration that could result in the need for long-term care and thus to promote healthy aging. Of those invited, 1178 gave written informed consent to being included in the structured survey. Of these 1178, we investigated 969 persons who agreed to respond to a questionnaire on medical care costs, the coverage of these costs under the NHI system, and medical care utilization derived from claim history files. The comprehensive health and lifestyle information for each subject at baseline allowed us to adjust for a variety of potential confounders. The protocol of this study was approved by the Institutional Review Board of the Tohoku University Graduate School of Medicine.

We excluded the subjects who provided incomplete data in the PA questionnaire ($n = 130$), or who had not been tested for physical performance ($n = 70$). Furthermore, we excluded all potential subjects with notable comorbidities that could influence the frequency and degree of PA, that is, those who reported being incapable of walking 50 m independently ($n = 58$) and those with a history of arthritis ($n = 107$). Of the remaining 604 subjects, we further excluded those who reported a history of stroke ($n = 26$), coronary heart disease ($n = 61$), cancer ($n = 33$), and the one subject reporting cognitive dysfunction (Mini-Mental State Examination [MMSE] score <18) in the baseline survey. As a result of these exclusions, the final study population comprised 483 (231 male and 252 female) subjects. The mean age was 75.5 years (standard deviation [SD] = 4.2).

Data on medical care costs

We prospectively collected data on medical care use and costs for all individuals in the cohort study that extended from August 2002 to March 2008. We obtained the NHI claims history files from the Miyagi NHI Association. These files included the total number of outpatient visits, the total number of days of inpatient care, and the charges for outpatient and inpatient care, respectively.

When a beneficiary was withdrawn from the NHI, the date and reason were coded on an NHI withdrawal history file. This file identified the survival and emigration status for each subject. Both the NHI claims and withdrawal history files were linked with our baseline survey data file, with the beneficiary's ID number functioning as the key code. Monthly medical expenditures for each subject were calculated by dividing the total medical expenditures throughout the observation period by the number of months observed. We used monthly values rather than cumulative values to avoid underestimating medical expenditures for subjects who died or emigrated during the follow up.

Assessment of PA

A self-reported single-item questionnaire was used to estimate the different levels of PA in each subject. The subject was asked whether he or she had performed any activities from the following categories in the previous 12 months: walking, brisk walking, or sports (e.g. aerobics, tennis, swimming, jogging, etc.). If they had participated in a given activity, the frequency of and duration of time spent in performing the activity were ascertained using the following categories: for frequency

Table 1 Definition of physical activity level ($n = 483$)

	Low		Moderate		High	
No. of participants	115	90	114	46	66	52
Walking	None	Low	High	Any	Any	Any
Brisk walking	None	None	None	Low	High	Any
Sports	None	None	None	None	None	Low and high
Walking						
None	115	0	0	14	41	22
Low	0	90	0	15	1	14
High	0	0	114	17	24	16
Brisk walking						
None	115	90	114	0	0	32
Low	0	0	0	46	0	7
High	0	0	0	0	66	13
Sports						
None	115	90	114	46	66	0
Low	0	0	0	0	0	48
High	0	0	0	0	0	4

High, at least 3–4 times/week for at least 30 min each time; low, reporting some activity in the past year, but not enough to meet high levels; none, no physical activity.

(i) 1–2 times/month; (ii) 1–2 times/week; (iii) 3–4 times/week; or (iv) almost every day; and for duration (per walk or workout) (i) 0–30 min (<30 min); (ii) 0.5–1 h (≥0.5 h, <1 h); (iii) 1–2 h (≥1 h, <2 h); (iv) 2–3 h (≥2 h, <3 h); (v) 3–4 h (≥3 h, <4 h); or (vi) 4 h or more (≥4 h). Among the levels of exercise intensity, sports were considered the highest, followed in order by brisk walking and walking. Each of the three types was further classified into three subcategories according to the frequency and duration of the walks or workouts as follows:[19,20] (i) high, at least 3–4 times/week for at least 30 min each time; (ii) low, some activity in the past year, but not enough to meet the criteria for the high group; and (iii) none, no PA. Finally, we used these categories and subcategories to define the following three levels of PA (Table 1): (i) low, no sports, no brisk walking, low amount of walking; (ii) moderate, no sports, low amount of brisk walking, any amount of walking; and (iii) high, any amount of sports, any amount of brisk walking, any amount of walking. Table 1 also shows the number of participants according to the PA levels.

Assessment of physical performance measurement

Leg muscle power (w/kg)

Bilateral leg muscle power was measured on a horizontal leg extension apparatus (Combi Anaeropress 3500, Tokyo, Japan). Participants were positioned well back on a seat, supported at the waist by a belt, and their feet were placed on a sliding board with the knee joints angled at 90°. The resistance of the sliding board was adjusted according to the bodyweight. Participants were asked to extend their knees to push away the sliding board as hard as they could. The leg extension power was then measured. The trials were separated by 15-s rest intervals. The average of the two highest leg power measurements among five trials conducted was recorded as the "leg muscle power" and the resulting power was divided by the bodyweight.

Functional reach (cm)

Participants were asked to reach as far forward as possible while maintaining a fixed base of support, with their feet placed comfortably apart (approximately shoulder-width) but in symmetrical sagittal alignment. The distance reached was measured (in cm) on a tape measure fixed to the wall. This test was repeated three times and the longest distance measured was recorded.[21]

Timed "Up & Go" test (s)

Participants were seated in a free-standing padded armchair (46 cm high) and asked to rise (with or without using the armrests), walk to a mark 3 m away, turn around, walk back to the chair and sit down. The time between consecutive risings from the seat and contact made with the back of the seat was measured (s). This test was repeated three times and the fastest walk was recorded.[22]