Table 5. HRs[a] and 95% CIs[a] of all-cause mortality in 21 038 men by BMI[a] category, stratified by age group

	BMI						
	<18.5	18.5–20.9	21.0–22.9	23.0–24.9	25.0–27.4	27.5–29.9	≥30.0
Total							
No.	732	3677	5617	5657	3726	1213	416
Person-years	6282	35 339	55 681	57 157	37 954	12 484	4162
No. of deaths	270	805	1004	861	513	165	67
Mortality rate[b]	43.0	22.8	18.0	15.1	13.5	13.2	16.1
Age-smoking-adjusted HRs	2.78 (2.42–3.18)	1.49 (1.35–1.64)	1.19 (1.09–1.22)	1.00 (reference)	0.90 (0.81–1.00)	0.90 (0.76–1.06)	1.11 (0.87–1.43)
Multivariate HRs1[c]	1.42 (1.23–1.65)	1.10 (0.99–1.22)	1.04 (0.95–1.14)	1.00 (reference)	1.01 (0.90–1.13)	1.10 (0.92–1.31)	1.44 (1.11–1.87)
Multivariate HRs2[d]	1.52 (1.31–1.76)	1.14 (1.03–1.26)	1.06 (0.96–1.16)	1.00 (reference)	1.00 (0.89–1.12)	1.06 (0.89–1.26)	1.39 (1.07–1.81)
Multivariate HRs3[e]	1.35 (1.15–1.59)	1.06 (0.95–1.19)	1.01 (0.92–1.12)	1.00 (reference)	0.99 (0.88–1.12)	1.05 (0.87–1.26)	1.42 (1.07–1.88)
40–64 y							
No.	310	2159	3591	3852	2637	903	312
Person-years	3053	21 992	36 885	40 026	27 421	9425	3221
No. of deaths	47	224	340	305	211	75	33
Mortality rate[b]	15.4	10.2	9.2	7.6	7.7	8.0	10.2
Age-smoking-adjusted HRs	1.76 (1.29–2.39)	1.25 (1.05–1.49)	1.17 (1.01–1.37)	1.00 (reference)	1.07 (0.90–1.28)	1.17 (0.91–1.51)	1.54 (1.08–2.21)
Multivariate HRs1[c]	1.26 (0.92–1.73)	1.07 (0.89–1.28)	1.11 (0.95–1.30)	1.00 (reference)	1.14 (0.95–1.37)	1.27 (0.97–1.66)	1.71 (1.17–2.50)
Multivariate HRs2[d]	1.32 (0.96–1.82)	1.09 (0.91–1.31)	1.12 (0.96–1.32)	1.00 (reference)	1.12 (0.93–1.35)	1.22 (0.93–1.60)	1.64 (1.12–2.40)
Multivariate HRs3[e]	1.24 (0.87–1.78)	1.11 (0.92–1.35)	1.13 (0.95–1.34)	1.00 (reference)	1.16 (0.96–1.41)	1.20 (0.90–1.61)	1.62 (1.07–2.45)
65–79 y							
No.	422	1518	2026	1805	1089	310	104
Person-years	3229	13 347	18 796	17 131	10 533	3059	941
No. of deaths	223	581	664	556	302	90	34
Mortality rate[b]	69.1	43.5	35.3	32.5	28.7	29.4	36.1
Age-smoking-adjusted HRs	1.88 (1.61–2.20)	1.26 (1.12–1.41)	1.06 (0.94–1.18)	1.00 (reference)	0.91 (0.79–1.05)	0.96 (0.77–1.19)	1.21 (0.86–1.71)
Multivariate HRs1[c]	1.49 (1.26–1.76)	1.11 (0.98–1.26)	1.01 (0.90–1.14)	1.00 (reference)	0.94 (0.81–1.09)	1.01 (0.80–1.27)	1.25 (0.87–1.80)
Multivariate HRs2[d]	1.59 (1.35–1.89)	1.16 (1.03–1.32)	1.03 (0.92–1.16)	1.00 (reference)	0.93 (0.80–1.07)	0.97 (0.77–1.23)	1.23 (0.86–1.76)
Multivariate HRs3[e]	1.48 (1.23–1.78)	1.09 (0.96–1.25)	0.98 (0.87–1.11)	1.00 (reference)	0.88 (0.76–1.03)	0.91 (0.71–1.17)	1.22 (0.83–1.79)

[a]HR, hazard ratio; CI, confidence interval; BMI, body mass index.
[b]Mortality rate was defined as number of deaths per 1000 person-years.
[c]Multivariate HRs1 were adjusted for age in 5-year categories; weight change since age 20 years (loss of 10.0 kg or more, loss of 5.0–9.9 kg, change of less than ±5.0 kg, gain of 5.0–9.9 kg, or gain of 10.0 kg or more); education (junior high school or less, high school, or college/university or higher); marital status (married or unmarried); cigarette smoking (never smoker, past smoker, current smoker consuming 1–19 cigarettes per day, or current smoker consuming at least 20 cigarettes per day); alcohol drinking (never drinker, past drinker, or current drinker); time spent walking per day (less than 1 hour, or 1 hour or longer); sports and physical exercise time per week (less than 1 hour, 1–2 hours, 3–4 hours, or 5 hours or longer); history of kidney disease (yes or no); history of liver disease (yes or no).
[d]Multivariate HRs2 were further adjusted for history of hypertension (yes or no) and history of diabetes (yes or no).
[e]Multivariate HRs3 excluded from multivariate HRs2 the 473 men who died within the 2 years after baseline.

reported BMI at baseline. Niedhammer et al showed that there is a systematic bias in self-reported weight and height.[29] However, we previously evaluated the validity of self-reported BMI, and demonstrated a high correlation and appropriate agreement between self-reported BMI and measured BMI in a subsample of 14 883 participants (r = 0.88, κ = 0.72). We consider this bias to be a nondifferential misclassification that is not dependent upon all-cause death. This misclassification weakens the true association toward the null. Third, as a result of stratification by age group, there was a possibility of beta error because of inadequate numbers of participants and events. Finally, there is a possibility of residual confounding by physical activity.

In summary, obesity increases mortality risk in middle-aged men, whereas underweight, rather than obesity, is associated with high mortality risk in elderly men. In women, obesity increases mortality risk in middle age, and underweight increases mortality risk irrespective of age. Although there

Table 6. HRs[a] and 95% CIs[a] of all-cause mortality in 22 934 women by BMI[a] category, stratified by age group

	BMI						
	<18.5	18.5–20.9	21.0–22.9	23.0–24.9	25.0–27.4	27.5–29.9	≥30.0
Total							
No.	928	3518	5498	5676	4556	1929	829
Person-years	9011	34 782	55 716	57 537	46 281	19 477	8313
No. of deaths	174	371	451	415	357	159	95
Mortality rate[b]	19.3	10.7	8.1	7.2	7.7	8.2	11.4
Age-smoking-adjusted HRs	2.66 (2.23–3.18)	1.48 (1.28–1.70)	1.12 (0.98–1.28)	1.00 (reference)	1.07 (0.93–1.23)	1.13 (0.94–1.36)	1.59 (1.27–1.99)
Multivariate HRs1[c]	1.49 (1.24–1.80)	1.15 (0.99–1.33)	0.99 (0.87–1.14)	1.00 (reference)	1.03 (0.89–1.19)	1.07 (0.89–1.30)	1.33 (1.05–1.69)
Multivariate HRs2[d]	1.58 (1.31–1.91)	1.19 (1.03–1.38)	1.01 (0.88–1.15)	1.00 (reference)	1.00 (0.87–1.16)	1.04 (0.85–1.26)	1.24 (0.97–1.57)
Multivariate HRs3[e]	1.44 (1.17–1.78)	1.18 (1.01–1.38)	1.02 (0.88–1.18)	1.00 (reference)	1.06 (0.91–1.24)	1.09 (0.88–1.34)	1.37 (1.07–1.77)
40–64 y							
No.	425	2135	3521	3770	2890	1227	489
Person-years	4416	21 274	35 734	38 262	29 435	12 484	4999
No. of deaths	32	92	137	128	104	49	28
Mortality rate[b]	7.2	4.3	3.8	3.3	3.5	3.9	5.6
Age-smoking-adjusted HRs	2.10 (1.43–3.10)	1.30 (0.99–1.70)	1.16 (0.91–1.48)	1.00 (reference)	0.99 (0.76–1.28)	1.11 (0.80–1.54)	1.59 (1.06–2.39)
Multivariate HRs1[c]	1.46 (0.96–2.22)	1.10 (0.82–1.47)	1.09 (0.85–1.40)	1.00 (reference)	1.00 (0.77–1.31)	1.06 (0.75–1.51)	1.47 (0.94–2.27)
Multivariate HRs2[d]	1.55 (1.02–2.36)	1.14 (0.85–1.52)	1.10 (0.86–1.41)	1.00 (reference)	0.98 (0.75–1.28)	1.01 (0.71–1.43)	1.38 (0.89–2.14)
Multivariate HRs3[e]	1.78 (1.13–2.81)	1.36 (1.00–1.86)	1.21 (0.92–1.59)	1.00 (reference)	1.02 (0.76–1.36)	0.99 (0.68–1.45)	1.32 (0.82–2.15)
65–79 y							
No.	503	1383	1977	1906	1666	702	340
Person-years	4595	13 508	19 982	19 275	16 845	6994	3314
No. of deaths	142	279	314	287	253	110	67
Mortality rate[b]	30.9	20.7	15.7	14.9	15.0	15.7	20.2
Age-smoking-adjusted HRs	1.67 (1.37–2.05)	1.26 (1.07–1.48)	1.00 (0.85–1.17)	1.00 (reference)	1.02 (0.86–1.21)	1.07 (0.86–1.34)	1.33 (1.02–1.73)
Multivariate HRs1[c]	1.47 (1.19–1.82)	1.14 (0.96–1.36)	0.95 (0.81–1.12)	1.00 (reference)	1.04 (0.87–1.24)	1.07 (0.85–1.35)	1.26 (0.95–1.68)
Multivariate HRs2[d]	1.56 (1.26–1.93)	1.19 (1.00–1.41)	0.96 (0.82–1.13)	1.00 (reference)	1.01 (0.85–1.21)	1.04 (0.83–1.31)	1.17 (0.88–1.55)
Multivariate HRs3[e]	1.45 (1.15–1.83)	1.17 (0.97–1.40)	0.96 (0.81–1.15)	1.00 (reference)	1.04 (0.86–1.25)	1.07 (0.83–1.37)	1.24 (0.92–1.68)

[a]HR, hazard ratio; CI, confidence interval; BMI, body mass index.
[b]Mortality rate was defined as number of deaths per 1000 person-years.
[c]Multivariate HRs1 were adjusted for age in 5-year categories; weight change since age 20 years (loss of 10.0 kg or more, loss of 5.0–9.9 kg, change of less than ±5.0 kg, gain of 5.0–9.9 kg, or gain of 10.0 kg or more); education (junior high school or less, high school, or college/university or higher); marital status (married or unmarried); cigarette smoking (never smoker, past smoker, current smoker consuming 1–19 cigarettes per day, or current smoker consuming at least 20 cigarettes per day); alcohol drinking (never drinker, past drinker, or current drinker); time spent walking per day (less than 1 hour, or 1 hour or longer); sports and physical exercise time per week (less than 1 hour, 1–2 hours, 3–4 hours, or 5 hours or longer); history of kidney disease (yes or no); history of liver disease (yes or no).
[d]Multivariate HRs2 were further adjusted for history of hypertension (yes or no) and history of diabetes (yes or no).
[e]Multivariate HRs3 excluded from multivariate HRs2 the 266 women who died within the 2 years after baseline.

was no significant interaction by age group or sex, the mortality risks associated with underweight and obesity may nevertheless be dependent on sex and age group.

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ORIGINAL ARTICLE: EPIDEMIOLOGY, CLINICAL PRACTICE AND HEALTH

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 2011; 11: 157–165.**

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

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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]

10-m maximum walk test (m/s)

Each participant was asked to walk 10 m at his or her maximum walking speed. A stopwatch was used for timing the walk, and a counter was used to ascertain the number of steps. To eliminate the periods of acceleration and deceleration, subjects started their laps 3 m before the beginning of the walkway and concluded them 3 m beyond its end. The test was repeated three times, and the data of the fastest walk were recorded. These data were used to determine each subject's maximum walking speed (m/s).[23]

As regards the assessment of physical performance, the results of the four tests described above were each stratified into tertiles. We assigned, for each category of physical performance tests, a score of 3 for those in the highest tertile, 2 for those in the moderate and 1 for those in the lowest tertile. These scores were then added, so that they ranged 4–12. Those with scores in the ranges of 4–6, 7–9 or 10–12 were categorized as having a low, moderate or high level of physical performance, respectively.

Assessment of other variables

Anthropometric measures (e.g. height, bodyweight) were recorded by a standardized protocol. Blood pressure (BP) was measured at home with an HEM747IC device (Omron Life Science, Tokyo, Japan) that uses the cuff-oscillometric method to generate a digital display of systolic and diastolic pressures. The mean of 15.6 ± 10.5 (SD) BP measurements was used as the BP value. Participants who did not measure their home BP on at least 3 days were treated as having missing information on hypertension.

Blood samples were drawn from the antecubital vein of the seated subject with minimal tourniquet use. Specimens were collected in siliconized vacuum glass tubes containing sodium fluoride for blood glucose and no additives for lipid analyses.

The total cholesterol (T-C) and blood glucose levels of the subjects were measured by enzymatic methods (T-C, Denka Seiken, Tokyo, Japan; blood glucose, Shino-Test, Tokyo, Japan). Data on smoking status, alcohol consumption and history of liver or renal disease were obtained from the questionnaire survey. A well-trained pharmacist confirmed the drug information.

History of physical illness was evaluated on the basis of the responses ("yes" or "no") to questions concerning the history of liver and renal disease. Depressive symptoms were assessed according to the Japanese version of the 30-item Geriatric Depression Scale (GDS).[24] The participants were further tested for cognitive ability based on the MMSE.[25] Information on smoking (never, former and current smoking) and drinking (never, former and current drinking) status of the participants was obtained from a questionnaire survey.

Definitions of variables

Hypertension was defined as a home systolic BP reading of 135 mmHg or above and/or a home diastolic BP reading of 85 mmHg or above or use of antihypertensive agents.[26] Diabetes was defined as a casual blood glucose concentration of 200 mg/dL or above or the current use of antidiabetic medication. Hyperlipidemia was defined as a T-C level of 220 mg/dL or above, or the current use of a lipid-lowering agent. A GDS score of 14 or more or the use of an antidepressant was taken to indicate depressive symptoms.[27] An MMSE score of less than 24 was taken to indicate cognitive impairment.[28]

Medical care use and its costs were indicated by the number of hospital days, number of physician visits and medical care costs (total, inpatient and outpatient). Inpatient medical care costs included the cost of almost all the medical treatment received at hospitals, such as that incurred in diagnostic tests, medication, surgery, supplies and materials, paying the physician's fees and other personnel costs, but did not include hospital meal fees. Outpatient medical care costs included the money spent in medical treatment at outpatient clinics, prescribed drugs and home care services provided by physicians, but did not include dental care.

The number of hospital days, the number of physician visits and the medical care costs were calculated as per capita per month indices, including all subjects and months of observation irrespective of whether or not the former had received care.

Statistical analysis

Descriptive data are presented as means (95% confidence interval [CI]) or percentages. The variables' differences according to the levels of PA were examined by the ANCOVA for continuous variables or by the multiple logistic regression analysis for variables of proportion. The impact of PA or physical performance on the medical costs and number of outpatient visits and hospital days, respectively, were examined using ANCOVA after adjustment for age, sex, body mass index (BMI), hypertension, hyperlipidemia, diabetes mellitus, history of liver or renal disease, depressive symptoms, cognitive status, smoking and drinking habits/history, and physical performance score. All *P*-values for linear trends were calculated by using the applicable category of the PA levels (low, 1; moderate, 2; high, 3). The interactions between the PA and covariables were assessed by testing the interaction term added to the adjusted model as a covariate. The impact of PA on medical costs and the number of outpatient visits and hospital days was

Table 2 Baseline characteristics of subjects by levels of physical activity ($n = 483$)

	Physical activity levels			*P* for trend
	Low	Moderate	High	
No. of participants	205	160	118	–
Age (years)	76.0 (75.4–76.6)	75.6 (74.9–76.2)	74.4 (73.6–75.1)	<0.001
Sex (female)	61.0	48.1	42.4	<0.001
BMI (kg/m^2)	23.8 (23.3–24.2)	23.4 (22.9–23.9)	23.4 (22.8–23.9)	0.26
Hypertension	70.2	67.5	60.2	0.07
Hyperlipidemia	45.4	44.4	39.0	0.29
Diabetes	7.3	9.4	8.5	0.65
Impaired cognitive function ($18 \leq$ MMSE < 24)	8.8	6.9	8.5	0.84
Depressive symptoms (GDS ≥14 or use of antidepressant)	20.0	16.9	9.3	0.02
Smoking status				
Current smoker	17.1	12.5	11.9	0.16
Ex-smoker	23.4	38.5	39.0	<0.01
Non-smoker	56.7	47.5	49.2	0.14
Drinking status				
Current drinker	40.0	41.9	50.9	0.07
Ex-drinker	11.2	12.5	15.3	0.30
Non-drinker	44.4	39.4	31.4	0.02
Self-reported illness				
Renal	6.8	5.0	3.4	0.18
Liver	6.3	6.9	5.1	0.71
Physical performance				
Knee extension power (w/kg)	9.3 (8.8–9.9)	11.3 (10.7–11.9)	13.1 (12.3–13.8)	<0.0001
Functional reach (cm)	30.2 (29.5–31)	31.3 (30.4–32.1)	32.1 (31.1–33.2)	<0.01
Timed "Up & Go" test (s)	9.3 (9.1–9.5)	8.9 (8.7–9.1)	8.3 (8.1–8.6)	<0.0001
10-m maximum walking (m/s)	1.7 (1.6–1.7)	1.8 (1.7–1.8)	1.9 (1.9–2.0)	<0.0001
Log-transformed total physical performance score	1.9 (1.9–2.0)	2.0 (2.0–2.1)	2.2 (2.1–2.2)	<0.0001

Variables are presented as least squares mean (95% confidence interval) or %. BMI, body mass index; GDS, Geriatric Depression Scale; MMSE, Mini-Mental State Examination.

examined in association with physical performance levels after adjustment for the above mediator.

In this paper, monetary values were converted into $US using the exchange rate of $US 1.00 = 115 ¥. $P < 0.05$ was regarded as statistically significant. SAS software ver. 9.1 was used for all statistical calculations.

Results

Descriptive

Of the 483 subjects, 205 (42.4%) were categorized at the lowest level of PA, 160 (33.1%) at the moderate level and 118 (24.4%) at the highest level. Table 2 shows the baseline characteristics of subjects categorized by the PA level. The mean age was significantly lower at the highest PA level (*P* for trend <0.001). Although not statistically significant, the BMI was highest at the lowest PA level (*P* for trend = 0.26). Physical performance (including the results of the four tests and the total physical performance score) and PA were found to be positively associated (*P* for trend <0.01). Generally, participants with a higher PA had a better physical performance score. The proportion of subjects who were female, had depressive symptoms and were non-drinkers was significantly lower in the higher PA levels (*P* for trend <0.001, =0.02 and 0.02, respectively). Although the difference was not statistically significant (*P* for trend = 0.07), the proportion of subjects with hypertension was lowest at the highest PA level. In contrast, the proportion of ex-smokers was significantly higher at the higher PA levels (*P* for trend <0.01). Other than the above-mentioned, no significant difference was observed among the PA levels.

Table 3 Association between total medical care costs and physical performance levels ($n = 483$)

Physical performance	Physical performance levels Low	Moderate	High	*P* for trend[†]
Leg muscle power (w/kg)	0.8–8.7	8.8–12.6	12.7–23.4	–
No. of participants	160	162	161	–
Total medical costs, $US	892.4 (652.7–1132.2)[‡]	858.0 (631.2–1084.9)	718.2 (481.5–954.8)	0.01
Functional reach (cm)	6.3–29.1	29.2–33.5	33.6–45.6	–
No. of participants	159	161	163	–
Total medical costs, $US	847.5 (616.5–1078.4)	816.5 (583.6–1049.5)	806.1 (568.9–1043.2)	0.46
Timed "Up & Go" test (s)	16.8–9.4	9.4–8.1	8.1–5.6	–
No. of participants	161	162	160	–
Total medical costs, $	857.6 (626.9–1088.3)	819.8 (583.6–1056.0)	794.8 (561.4–1028.2)	0.25
10-m maximum walking (m/s)	0.9–1.6	1.7–1.9	1.9–3.1	–
No. of participants	160	162	161	–
Total medical costs, $US	898.6 (664.1–1133.0)	801.2 (572.1–1030.3)	795.5 (559.6–1031.5)	0.08
Total physical performance score	4–6	7–9	10–12	–
No. of participants	138	192	153	–
Total medical costs, $US	898.0 (662.0–1134.1)	823.4 (595.7–1051.1)	724.1 (485.1–963.2)	0.01

[†]Adjusted for age, sex, body mass index, hypertension, hyperlipidemia, diabetes, history of liver disease or renal disease, depressive symptoms, impaired cognitive function, smoking status, drinking status; [‡]Variables are presented as least-squares mean (95% confidence interval) (all such values).

Association between physical performance and PA or medical care costs per person

Table 3 shows the relationship between medical care costs and physical performance measurements. Levels of physical performance tests were stratified into tertiles. Although medical care costs tended to be higher in the poorer physical performance tertiles, the leg muscle power and total physical performance score were found to be the only statistically significant measures (*P* for trend = 0.01) among the four tests administered after adjustment for covariables. Although not statistically significant, the medical care costs were lowest in the highest 10-m maximum walking group (*P* for trend = 0.08).

Association between PA levels and medical care costs per person

Table 4 shows the adjusted association between the PA level and the medical care costs and the average number of days of hospital stay or visits. After adjustment for covariables, the significant inverse relation of PA levels with inpatient cost, average number of days of hospital stay and total cost was observed (*P* for trend = 0.02, 0.046, and 0.02, respectively). No significant interaction was observed between the physical performance score and PA levels for inpatient, outpatient or total medical care costs (data not shown). In contrast, no relation was found between the levels of PA and outpatient expenditures or average number of hospital visits in all models. Similar results were also observed when men and women were analyzed separately. No significant interaction was observed between the physical performance score and the sex of the patient regarding inpatient, outpatient or total medical care costs. Stratified association between the PA levels and the total medical care costs (least-squares mean, 95% CI) by physical performance levels after adjustment for variables in the full multivariate model in Table 4 are shown in Figure 1. Except for a small sample ($n = 14$) group characterized by high PA with lower physical performance, the PA was inversely associated with medical cost in all the physical performance categories.

Discussion

The main finding of this study was that higher PA levels were associated with lower medical care costs and hospitalization days among Japanese community-dwelling elderly individuals. Higher physical performance levels were also associated with lower medical care costs. However, the inverse association between PA and medical care costs persisted even after adjustment for the level of physical performance (*P* for interaction = 0.48). These results suggested that the beneficial effect of PA on medical cost might be consistently observed irrespective of their baseline physical performance.

The strength of our study lies in the fact that we have measured both the PA and the physical performance. The unique characteristics of the study enabled us to clarify whether the PA itself predicts the medical cost or whether it merely marks the physical performance.

Table 4 Association between physical activity levels and medical care costs ($n = 483$)

	Physical activity levels Low	Moderate	High	*P* for trend
No. of participants	205	160	118	–
Inpatient data, $US				
Model 1†	421.8 (227.4–616.1)‡	323.7 (123.4–524.0)	297.3 (90.0–504.5)	<0.01
Model 2§	389.3 (190.8–587.8)	296.7 (93.7–499.8)	282.3 (74.3–490.4)	0.02
No. of hospital days†				
Model 1†	1.9 (1.1–2.7)	1.5 (0.7–2.3)	1.4 (0.6–2.3)	0.02
Model 2§	1.7 (0.9–2.6)	1.4 (0.5–2.2)	1.4 (0.5–2.2)	0.046
Outpatient data, $US				
Model 1†	453.4 (346.6–560.3)	427.7 (317.6–537.9)	426.1 (312.2–540.1)	0.28
Model 2§	438.0 (328.9–547.2)	414.4 (302.7–526.0)	419.7 (305.3–534.0)	0.48
No. of physician visits†				
Model 1†	6.5 (4.6–8.4)	6.6 (4.6–8.5)	6.6 (4.5–8.6)	0.87
Model 2§	6.4 (4.4–8.3)	6.5 (4.4–8.5)	6.5 (4.4–8.6)	0.76
Total costs, $US				
Model 1†	875.2 (650.2–1100.2)	751.4 (519.5–983.4)	723.4 (483.4–963.4)	<0.01
Model 2§	827.3 (598.0–1056.7)	711.1 (476.4–945.8)	702.0 (461.6–942.4)	0.02

†Adjusted for age, sex, body mass index, hypertension, hyperlipidemia, diabetes, history of liver disease or renal disease, depressive symptoms, impaired cognitive function, smoking status, drinking status. ‡Variables are presented as least-squares mean (95% confidence interval) (all such values). §Adjusted for model 1 + total physical performance score.

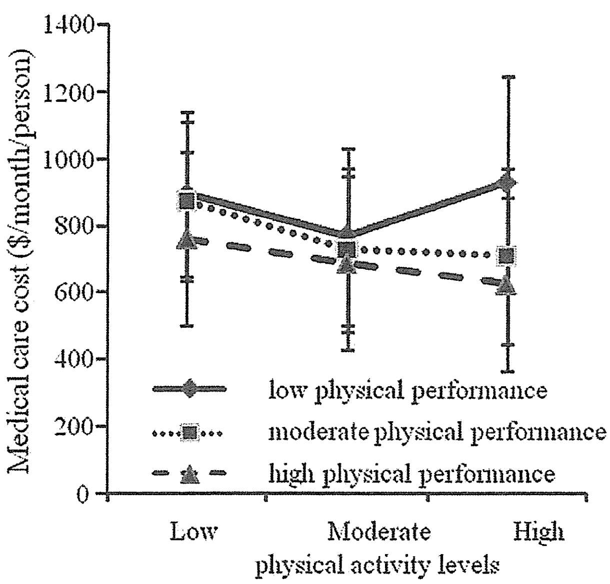

Figure 1 Association between physical activity levels and total medical care costs stratified by physical performance levels. Results from an analysis of covariance model adjusting for age, sex, body mass index, hypertension, hyperlipidemia, diabetes mellitus, history of liver disease or renal disease, depressive symptoms, impaired cognitive function, smoking status and drinking status. Variables indicate the adjusted least-squares mean. Error bars indicate 95% confidence intervals. Currency $US.

Individual reasons for medical treatment were not identified, but the fact that inpatient but not outpatient costs were higher among the community-dwelling subjects with lower levels of PA implies that these subjects may have suffered acute medical conditions requiring inpatient treatment. The outpatient care costs did not differ among the groups. The outpatient care costs were not influenced by the level of PA, partly because the proportion of elderly patients receiving medication for chronic diseases that did not affect their daily PA (e.g. hyperlipidemia or hypertension) did not differ among the groups, and such medication was mostly prescribed regularly for a long period of time. It should be noted that only one-fifth of the subjects in each group were not medicated.

As we have previously reported, it was found in a population study involving 27 431 Japanese men and women aged 40–79 years that those who walked for more than 1 h per day paid less for medical care.[10] We reported that both inpatient and outpatient costs taken cumulatively were smaller among the active walkers, which seems to conflict with our present result. This is probably because in the earlier study the population was younger and more than 70% of the participants reported that their health was good or excellent. Another factor responsible for the conflict in results might be the difference in the methods employed for estimating PA. Therefore, it is most likely that the majority of the previous study population was non-medicated and did not suffer from chronic diseases, which stands in remarkable contrast with the present study population. Wang *et al.* also reported in their cross-sectional study that the frequency of PA had a strong dose–response effect on health-care costs in those above the age of 65 years.[9] A 10-year follow up of the participants in a randomized clinical trial of walking in the USA revealed that the subjects in the walking group continued to walk longer and had lower hospitalization rates than those in the control group.[29] However, the physical performance of the participants was not evaluated in any of the previous studies.

By excluding the subjects with a history of stroke, cancer or coronary heart disease who potentially incur greater medical care costs than those without a similar history, the study population's selection bias was sufficiently minimized. The fact that the accumulated medical care cost during the initial 6 months did not differ among the groups shows that leading bias was minimized.

A stratified analysis by physical performance levels showed that the inverse dose–response relationship between total medical care costs and PA was observed in the moderate and high physical performance levels (Fig. 1). In the low physical performance level, the total medical care costs were highest at the highest PA level. Although we cannot validly explain this result, the number of subjects in the highest PA level was very small ($n = 14$), and therefore the mean medical care cost for that level would be imprecise.

This study has several limitations. First, because all the assessment were carried out in a public facility, the participants were sufficiently active and healthy to participate in the survey; therefore, it is possible that the current results would not be applicable to subjects at a higher risk. Moreover, because arthritis and remarkably low physical function might influence the frequency and degree of PA, and many diseases such as stroke, coronary heart disease and cancer can be a reason for large medical care cost at baseline, we also excluded these participants. Therefore, our results may not represent the general elderly population. However, we believe that these exclusions were necessary to investigate the relation of PA with medical care cost. Second, the diagnosis for each instance of medical care use was not available. This prevented an examination of the effects of exercise on particular diseases. Third, the intensity of walking, brisk walking and sports were not directly measured. Therefore, the proportional amount of PA in terms of the energy expenditure required for reducing medical care costs cannot be determined. However, because a person can easily discriminate his or her own "brisk walking" from ordinary walking,[30] it was suggested that the categorization of relative walking intensity based on the subjects' own perceptions was reliable.

In conclusion, this prospective study indicates that a higher level of PA was associated with lower medical care costs irrespective of physical performance among the elderly Japanese.

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The association between neighborhood social capital and self-reported dentate status in elderly Japanese – The Ohsaki Cohort 2006 Study

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Abstract – *Objectives:* Little is known about the influence of social capital on dental health. The aim of the present cross-sectional study was to determine the association between neighborhood social capital, individual social networks and social support and the number of remaining teeth in elderly Japanese. *Methods:* In December 2006, self-administered questionnaires were sent to 31 237 eligible community-dwelling individuals (response rate: 73.9%). Included in the analysis were 21 736 participants. Five neighborhood social capital variables were calculated from individual civic networks, sports and hobby networks, volunteer networks, friendship networks and social support variables. We used multilevel logistic regression models to estimate the odds ratio (OR) of having 20 or more teeth according to neighborhood social capital variables with adjustment for sex, age, individual social networks and social support, educational attainment, neighborhood educational level, dental health behavior, smoking status, history of diabetes and self-rated health. *Results:* The average age of the participants was 74.9 (standard deviation; 6.6) years, and 28.5% of them had 20 or more teeth. In the univariate multilevel model, there were statistically significant associations between neighborhood sports and hobby networks, friendship networks and self-reported dentate status. In the multivariable multilevel model, compared with participants living in lowest friendship network neighborhoods, those living in highest friendship network neighborhoods had an OR 1.17 (95% confidence interval, 1.04–1.30) times higher for having 20 or more teeth. *Conclusions:* There is a significant association between one network aspect of neighborhood social capital and individual dentate status regardless of individual social networks and social support.

Key words: dental status; multilevel analysis; remaining teeth; social capital; social epidemiology

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Increasing evidence suggests that a broad range of social determinants, not only biomedical factors, influence general health (1). Recent studies have revealed that social capital, a social determinant, has an important influence on health. Social capital has been defined as the features of social organization, such as civic participation, norms of reciprocity, and trust in others, that facilitate cooperation for mutual benefit (2). Social capital as a property of communities is distinguished from social capital as an attribute of individuals, which approximates the concepts of social support and

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social networks (3). It can be broadly defined as the density of trust, networks, or cooperation within a given community (4). In epidemiological studies, community-level social capital is often measured as an aggregated index of individual social networks or social support in each neighborhood (5), and a multilevel model is applied to distinguish the effects of individual- and community-level social capital on individual health (6).

Interest has also been focused on the importance of social determinants for oral health (7). However, only a few studies have examined the association between social capital and oral health. Previous cross-sectional studies examined the associations between social capital and oral health among 1302 students aged 14–15 years in Brazil: Empowerment as a social capital variable was investigated for its relationship with oral trauma (8) and dental caries (9). Another study examined the relationship between social capital and deciduous caries in 3301 3-year-old children: Multilevel analysis showed a beneficial contextual effect of social cohesion, one of the dimensions of social capital, on occurrence of deciduous caries (10). Association between the horizontal and vertical dimensions of social capital and the number of remaining teeth of 5560 elderly people was also examined, results showing a beneficial association between horizontal social capital and the number of remaining teeth (11).

Previous studies have suggested positive contextual effects on dental health. Both individual social networks and social support may mediate the association between neighborhood social capital and oral health. However, no study has simultaneously examined the association between neighborhood social capital, individual social networks and social support and oral health. These social determinants influence health status through subsequent life trajectories (12). The number of remaining teeth in elderly reflects the accumulative experience of dental caries, periodontal disease, dental injury, dental treatment and dental health behavior through their life-course. The aim of the present study was to determine the association between neighborhood social capital, individual social networks and social support and the number of remaining teeth in elderly Japanese.

Materials and methods

Setting and participants

This was a prospective cohort study, named The Ohsaki Cohort 2006 study, for which we analyzed cross-sectional data from the baseline survey of the study (13). The population and population density of Ohsaki city in 2005 were 138 141 and 173 person/km^2, respectively. The average age of the total resident population of the Ohsaki city was 44.2 years; 42.3 for men and 45.9 for women. Twenty-three percent of the population was 65 years or older. Among men, 19% were 65 years of age or older, while among women the rate was 27%. There were 69 208 workers; 19% in the manufacturing industry, 16% in the retail industry, 11% in the agricultural industry, 10% in the construction industry, and 8% in the medical and welfare industry. There were 15 hospitals, 85 clinics and 52 dental clinics.

There were two kinds of questionnaires in the Ohsaki cohort study: a questionnaire for persons aged 40–64 years and one for persons 65 years or older (13). Our study analyzed data obtained from those aged 65 years or older. The source population for the baseline survey comprised community-dwelling individuals aged 65 years or over, who were included in the Residential Registry for Ohsaki City. The Residential Registry identified 31 694 residents aged 65 years or older (12 750 men; 18 944 women) in Ohsaki city. The baseline survey was conducted from December 1 to December 15, 2006. A questionnaire was distributed by the heads of individual administrative districts to individual households and collected by mail. Of the 31 694 persons age 65 or over, 457 were found to be ineligible due to death, immigration, or hospitalization, yielding an eligible population of 31 237. The baseline questionnaires were collected from 23 394 persons, and valid responses were received from 23 091 (response rate: 73.9%, 9605 men and 13 486 women), who finally formed the study population of cohort participants. We excluded participants who did not respond to the items concerning administrative district (n = 252) and the number of remaining teeth (n = 1607). Consequently, the analyzed population consisted of 21 736 participants.

The Ohsaki city defined the municipal ordinance as administrative districts to improve efficiency of administration and citizens' welfare. The subjects were nested in 356 administrative districts, which we defined as neighborhoods. The analyzed population in each 356 administrative districts distributed as follows: 34 people = 25th percentile, 54 people = 50th percentile, 80 people = 75 percentile. The range of the response rates among the neighborhoods was relatively narrow. The distribution of the response rates of the whole Ohsaki cohort study including the respondents aged 40–64 among the 356 administrative districts was as follows: 60.4% = 25th percentile, 67.1% = 50th percentile, 73.0% = 75 percentile.

The study protocol was reviewed and approved by the Ethics Committee of Tohoku University Graduate School of Medicine.

Baseline survey

The baseline questionnaires consisted of the following details in sequence: (i) the frailty checklist (i.e. the Kihon Checklist in Japanese) – a tool developed to screen for frailty – (14), (ii) history of diseases, (iii) health status over the last year, (iv) smoking status, (v) alcohol drinking status, (vi) dietary habits (15), (vii) past body weight, height and educational status, (viii) health status in general, (ix) pain, (x) daily activities, (xi) sports and exercise (16, 17), (xii) psychological distress (K6) (18, 19), (xiii) social support (20), (xiv) participation in community activities and (xv) dental status.

Measurement of individual-level variables

Participation in community activities was used as a source of social network variables. Four questions composed of four kinds of networks, namely, civic networks, sports and hobby networks, volunteer networks and friendship networks, were included as follows: (i) civic networks, for example, participation in civic activities, resident and neighborhood associations and so on, (ii) sports and hobby networks, for example, participation in sports activities, culture activities, lifelong learning and so on, (iii) volunteer networks, for example, participation in volunteer activities, welfare activities, sports coaching, disaster and crime prevention, environment activities and (iv) friendship networks, for example, participation in class reunions, social gatherings and so on. Choices as to the frequency of participation in each of the four kinds of network were 'never', 'several times a year', 'once a month', 'a few times a month', 'once a week', 'a few times a week' and 'more than 4 times a week'. When we included the responses in the models, they were divided into three categories as follows: (i) lowest social network (never participated), (ii) medium social network (participated several times a year) and (iii) highest social network (participated at least once a month).

The degree of social support available to each person was assessed by asking the following five questions (20): (i) Do you have someone with whom you can consult when you are in trouble?, (ii) Do you have someone with whom you can consult when your physical condition is not good?, (iii) Do you have someone who can help you with your daily housework?, (iv) Do you have someone who can take you to a hospital when you do not feel well? and (v) Do you have someone who can take care of you when you are ill in bed? This social support questionnaire consisted of five questions, each requiring a 'yes' or 'no' answer. This questionnaire was only available in Japanese. The validity and reliability of the questionnaire were not evaluated. The percentages of the respondents who answered 'no' to each five question were low: (i) 9.5%, (ii) 6.1%, (iii) 13.5%, (iv) 6.9% and (v) 12.7%. Therefore we aggregated the five questions into one social support variable, which had three categories as follows: (i) lowest social support (responding 'yes' to less than three questions), (ii) medium social support (responding 'yes' to four questions) and (iii) highest social support (responding 'yes' to five questions).

The self-reported number of remaining teeth was used as an index of the dentate status. Retention of a minimum of 20 functional teeth at age 65 years or over was an oral health goal specified in the WHO and Federation Dentaire Internationale 'Global Goals for Oral Health in the year 2000' (21). The goal set by the Japan Dental Association was retention of a minimum of 20 functional teeth at the age of 80. Therefore, the number of remaining teeth, the outcome variable of this study, was used as a dichotomous variable: either ≥20 teeth or ≤19 teeth.

We also asked about dental health behavior: daily frequency of daily tooth brushing (free-answer question divided into three categories as follows: (i) less than 2 times, (ii) 2 times and (iii) 3 times or more), duration of tooth brushing at one time (<3 min, 3–5 min, 5 min or more), the use of dental floss or interdental brushes (yes, no), having a dental check-up at least once a year (yes, no), and frequency of intake of sweet foods (almost never, 1–2 times per month, 1–2 times per week, 3–4 times per week, almost every day and divided into three categories as follows: (i) 1–2 times per month or less, (ii) 1–4 times per week and (iii) almost every day). Smoking status (never, former, current) and history of diabetes (yes, no) were also investigated as risk factors of periodontal disease. As people in good health may tend to have good social networks, and people in poor health may tend to have much social support, the questionnaire also asked about self-rated health (excellent, good, fair, poor, and very poor and divided into three categories as follows: (i) good, (ii) fair and (iii) poor) as a covariate for social networks and social support. We also investigated the number of years of educational attainment since 6 years of age as an indicator of socioeconomic status. The number of years were divided into four categories as follows: (i) ≤9 years, (ii) 10–12 years, (iii) 13–15 years and (iv) ≥16 years.

Measurement of neighborhood-level variables

Social capital can be broken down into cognitive and structural components. We used social support and social network aspects of social capital, because perceived social support is regarded as a part of cognitive social capital (5) and social network is regarded as a part of structural social capital (5).

We created neighborhood variables by aggregating individual level data. Therefore, to determine the association between neighborhood social capital and health outcome, we adjusted for individual social network and support variables (22). All neighborhood-level variables were calculated on the basis of 356 administrative districts.

We focused on the proportion of respondents who had one or more social networks. The proportions of participants in each neighborhood who answered social network questions with answers other than 'never' were calculated for each of the four kinds of networks. The proportion of participants in each neighborhood who answered 'yes' to all five social support questions was also calculated. The neighborhoods were divided into three categories (lowest, medium or highest) based on the 33rd and 66th percentiles of each of the four social network rates and one social support rate. These five variables were used as neighborhood social capital variables.

Both individual and neighborhood socioeconomic status were considered to be associated with social capital (23). Therefore, both individual and neighborhood educational variables were included in the model. Neighborhood educational level was used as an index of neighborhood socioeconomic status. The mean number of years of education was calculated for each neighborhood. The neighborhoods were divided into three categories (lowest, medium, or highest) based on the 33rd and 66th percentiles of the average number of years of education.

Within Japan, there is no community fluoridated water supply. Therefore, we did not include water fluoridation as a variable in the multilevel models.

Analysis

In our data set, individuals (first-level) were nested in communities (second-level). We applied multilevel models (24, 25) to estimate the association of neighborhood social capital, individual social networks and social support with individual dentate status, controlling for one another, the contextual effect of neighborhood educational level and the compositional effects of individual educational attainment, health behavior and self-rated health. Multilevel logistic regression models with random intercepts and fixed slopes were estimated using the MLwiN 2.10 software package (26). The number of remaining teeth (≥20 or ≤19) was used as the outcome variable. Individual and neighborhood fixed parameters were converted to odds ratios (OR) with 95% confidence intervals (95% CI). In model 1, adjustments were made for all neighborhood social capital variables simultaneously to check the fixed and random parameters. In model 2, we included sex, age, all neighborhood social capital variables, educational level, individual social networks and social support and educational attainment variables simultaneously. In model 3, adjustments were made for sex, age, and all explanatory variables simultaneously. The univariate multilevel OR and random parameter of the intercept-only model were also estimated.

Results

The average age of the 21 736 participants (9126 male and 12 610 female) in the 356 administrative neighborhoods was 74.9 (standard deviation; 6.6) years. The prevalence of respondents having 20 or more teeth and that of those having 19 or less teeth were 28.5% (95% confidence interval; 27.9–29.1) and 71.5% (95% CI; 70.9–72.1), respectively.

Table 1 shows the distribution and univariate association between explanation variables and dentate status. Univariate OR were calculated by multilevel logistic regression analyses. There were statistically significant associations between neighborhood sports and hobby networks, friendship networks, educational level and dentate status. Four individual social network variables, educational attainment, all health behavior variables,

Table 1. Distribution of characteristics of individual- and neighborhood-level variables and univariate multilevel OR for remaining teeth

Variables		No. of participants who had 20 or more teeth (%)	No. of participants who had 19 or less teeth (%)	Univariate multilevel OR (95% CI)	*P*-value
Neighborhood-level variables					
Social capital					
Civic network	Lowest	2113 (28.5)	5289 (71.5)	1.00 (referent)	
	Medium	2030 (28.5)	5090 (71.5)	1.00 (1.00–1.00)	0.964
	Highest	2054 (28.5)	5160 (71.5)	1.03 (0.93–1.14)	0.568
Sports and hobby network	Lowest	1808 (25.1)	5407 (74.9)	1.00 (referent)	
	Medium	2089 (28.8)	5160 (71.2)	1.22 (1.10–1.35)	<0.001
	Highest	2300 (31.6)	4972 (68.4)	1.37 (1.24–1.51)	<0.001
Volunteer network	Lowest	2026 (27.4)	5366 (72.6)	1.00 (referent)	
	Medium	2084 (28.9)	5134 (71.1)	1.07 (0.97–1.18)	0.181
	Highest	2087 (29.3)	5039 (70.7)	1.10 (0.99–1.22)	0.070
Friendship network	Lowest	1798 (25.0)	5394 (75.0)	1.00 (referent)	
	Medium	2074 (28.5)	5195 (71.5)	1.19 (1.08–1.31)	<0.001
	Highest	2325 (32.0)	4950 (68.0)	1.41 (1.28–1.56)	<0.001
Social support	Lowest	2079 (28.4)	5229 (71.6)	1.00 (referent)	
	Medium	2085 (28.8)	5163 (71.2)	1.04 (0.93–1.17)	0.509
	Highest	2033 (28.3)	5147 (71.7)	1.00 (1.00–1.00)	0.982
Neighborhood educational level	Lowest	1744 (24.3)	5429 (75.7)	1.00 (referent)	
	Medium	2086 (28.6)	5212 (71.4)	1.23 (1.12–1.35)	<0.001
	Highest	2367 (32.6)	4898 (67.4)	1.49 (1.36–1.64)	<0.001
Individual-level variables					
Social network					
Civic network	Lowest	2677 (25.1)	7999 (74.9)	1.00 (referent)	
	Medium	1151 (32.9)	2347 (67.1)	1.49 (1.37–1.62)	<0.001
	Highest	1717 (36.5)	2982 (63.5)	1.76 (1.63–1.90)	<0.001
Sports and hobby network	Lowest	2577 (24.0)	8154 (76.0)	1.00 (referent)	
	Medium	643 (33.6)	1270 (66.4)	1.61 (1.45–1.79)	<0.001
	Highest	2264 (38.2)	3655 (61.8)	1.93 (1.80–2.07)	<0.001
Volunteer network	Lowest	3390 (26.1)	9614 (73.9)	1.00 (referent)	
	Medium	885 (35.8)	1584 (64.2)	1.61 (1.47–1.76)	<0.001
	Highest	1057 (41.4)	1494 (58.6)	2.01 (1.84–2.20)	<0.001
Friendship network	Lowest	2383 (23.6)	7698 (76.4)	1.00 (referent)	
	Medium	2157 (36.3)	3777 (63.7)	1.84 (1.71–1.98)	<0.001
	Highest	700 (38.7)	1108 (61.3)	2.02 (1.82–2.25)	<0.001
Social support	Lowest	903 (28.3)	2290 (71.7)	1.00 (referent)	
	Medium	672 (27.3)	1792 (72.7)	0.96 (0.85–1.08)	0.493
	Highest	4558 (28.9)	11 220 (71.1)	1.04 (0.95–1.14)	0.383
Educational attainment	≤9 years	1534 (23.3)	5063 (76.7)	1.00 (referent)	
	10–12 years	2522 (30.4)	5787 (69.6)	1.41 (1.31–1.52)	<0.001
	13–15 years	1283 (34.3)	2458 (65.7)	1.69 (1.55–1.85)	<0.001
	≥16 years	474 (41.1)	680 (58.9)	2.18 (1.91–2.49)	<0.001
Age	65–69	2348 (45.3)	2834 (54.7)	1.00 (referent)	
	70–74	2088 (33.6)	4118 (66.4)	0.61 (0.57–0.66)	<0.001
	75–79	1168 (22.2)	4099 (77.8)	0.34 (0.32–0.38)	<0.001
	80–84	431 (13.8)	2687 (86.2)	0.19 (0.17–0.22)	<0.001
	≥85	162 (8.3)	1801 (91.7)	0.11 (0.09–0.13)	<0.001
Sex	Female	3309 (26.2)	9301 (73.8)	1.00 (referent)	
	Male	2888 (31.6)	6238 (68.4)	1.30 (1.22–1.38)	<0.001
Health behavior					
Daily frequency of toothbrushing	< 2 times	1986 (23.9)	6327 (76.1)	1.00 (referent)	
	2 times	2649 (34.6)	5018 (65.4)	1.65 (1.54–1.77)	<0.001
	≥3 times	1213 (31.9)	2588 (68.1)	1.45 (1.33–1.58)	<0.001
Brushing time (minutes)	<3 min	3243 (25.3)	9584 (74.7)	1.00 (referent)	
	3–5 min	2258 (37.2)	3818 (62.8)	1.74 (1.63–1.86)	<0.001
	≥5 min	599 (46.1)	700 (53.9)	2.50 (2.22–2.81)	<0.001
Use of dental floss or interdental brushes	No	4784 (25.0)	14 318 (75.0)	1.00 (referent)	
	Yes	1413 (53.6)	1221 (46.4)	3.39 (3.12–3.69)	<0.001

Table 1. Continued

Variables		No. of participants who had 20 or more teeth (%)	No. of participants who had 19 or less teeth (%)	Univariate multilevel OR (95% CI)	*P*-value
Dental check-up at least once a year	No	3697 (25.3)	10 937 (74.7)	1.00 (referent)	<0.001
	Yes	2292 (40.6)	3355 (59.4)	2.00 (1.87–2.14)	<0.001
Frequency of intake of sweet foods	Almost every day	813 (22.8)	2747 (77.2)	1.00 (referent)	
	1–4 times/ week	2984 (29.5)	7117 (70.5)	1.41 (1.29–1.54)	<0.001
	≤1–2 times/ month	1961 (31.7)	4225 (68.3)	1.56 (1.42–1.72)	<0.001
Smoking status	Current	592 (24.1)	1861 (75.9)	1.00 (referent)	
	Past	1408 (28.3)	3574 (71.7)	1.23 (1.10–1.38)	<0.001
	Never	3453 (30.2)	7964 (69.8)	1.38 (1.25–1.53)	<0.001
History of diabetes	Yes	671 (25.7)	1943 (74.3)	1.00 (referent)	
	No	5526 (28.9)	13 596 (71.1)	1.20 (1.09–1.32)	<0.001
Self-rated health	Poor	1006 (21.6)	3655 (78.4)	1.00 (referent)	
	Fair	2985 (29.3)	7211 (70.7)	1.51 (1.39–1.64)	<0.001
	Good	2138 (32.6)	4416 (67.4)	1.75 (1.60–1.91)	<0.001

history of diabetes and self-rated health also showed significant associations.

We compared the characteristics of participants in the lowest and highest categories of neighborhood social capital, individual social networks and support variables (Table 2). We showed the percentage of participants within one category of each variable: for example, 41.6% of male participants were included in the lowest civic network category. In contrast, 59.4% (not shown in the table) of female participants were included in the lowest civic network category. There were no marked differences between the civic network aspects of social capital and the characteristics of the participants. A higher proportion of participants residing in the highest sports and hobby network neighborhoods and highest friendship network neighborhoods had 20 or more teeth, lived in the highest educational level neighborhoods, and had better oral health behavior, except for the frequency of intake of sweet foods. A higher proportion of participants residing in the highest volunteer network neighborhoods lived in the highest educational level neighborhoods. There were no marked differences between the social support aspects of social capital and the characteristics of the participants. A higher proportion of participants in the highest category of civic networks had 20 or more teeth, had a longer period of education, had better oral health behavior except for the frequency of intake of sweet foods, and had good self-rated health. A higher proportion of participants in the highest category of sports and hobby networks, volunteer networks and friendship networks was male, had 20 or more teeth, lived in neighborhoods with a higher educational level, had a longer period of education, had better oral health behavior except for the frequency of intake of sweet foods, and had good self-rated health. A higher proportion of participants in the highest category of social support had good self-rated health.

Table 3 shows the results of multivariable multilevel logistic regression analyses. Model 1 included all neighborhood social capital variables simultaneously. There were beneficial statistically significant associations between neighborhood sports and hobby networks, friendship networks and dentate status. Model 2 included sex, age, all neighborhood social capital variables, educational level, individual social networks and social support and educational attainment variables simultaneously. After adjusting for neighborhood educational level, individual social networks, social support and education attainment, neighborhood friendship network variable still had a significant association with dentate status. Model 3 adjusted for sex, age, and all explanatory variables simultaneously. Compared with the participants living in lowest friendship network neighborhoods, those living in medium friendship network neighborhoods had an OR 1.10 times higher for having 20 or more teeth and those living in highest friendship network neighborhoods had an OR 1.17 times higher for having 20 or more teeth. Compared with the participants living in the lowest educational level neighborhoods, those living in the highest educational level neighborhoods had an OR 1.17 times higher for having 20 or more teeth.

Table 2. Demographical distribution of lowest and highest categories of neighborhood social capital, individual social networks and social support variables

	Civic network		Sports and hobby network		Volunteer network		Friendship network		Social support	
	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest
Neighborhood social capital variables										
Number of participants	7402	7214	7215	7272	7392	7126	7192	7275	7308	7180
Age, year, mean ± SD	74.9 ± 6.6	75.1 ± 6.6	75.4 ± 6.6	74.5 ± 6.5	75.1 ± 6.6	74.7 ± 6.6	75.4 ± 6.7	74.5 ± 6.5	74.7 ± 6.5	75.2 ± 6.7
Sex, Male (%)	41.6	41.6	41.5	42.8	41.2	42.7	41.0	42.8	41.9	41.4
Number of remaining teeth, ≥20 teeth (%)	28.5	28.5	25.1	31.6	27.4	29.3	25.0	32.0	28.4	28.3
Neighborhood educational level, highest (%)	31.2	34.4	14.3	50.6	26.3	36.7	14.0	55.7	34.1	28.6
Education attainment, ≥16 years (%)	5.3	5.2	3.2	6.8	4.6	5.3	3.4	7.3	5.6	4.5
Daily frequency of toothbrushing, ≥3 times (%)	19.8	18.3	16.3	21.2	18.4	19.5	16.4	21.3	18.4	19.3
Brushing time (minutes), ≥5 minutes (%)	6.9	5.9	5.5	7.0	6.4	6.3	5.7	6.9	6.9	5.9
Use of dental floss or interdental brushes, yes (%)	13.0	11.0	9.6	14.4	11.8	11.8	10.0	14.1	12.4	11.4
Dental check-up at least once a year, yes (%)	27.9	27.5	25.5	29.6	27.6	29.2	26.0	29.8	28.5	27.0
Frequency of intake of sweet foods, 1–2 times/month	31.0	30.1	31.6	31.0	31.9	31.1	31.9	29.9	31.5	29.7
Smoking status, never, (%)	60.3	61.8	61.6	59.8	60.3	60.9	61.6	59.8	59.3	62.4
History of diabetes, no (%)	87.6	88.2	88.5	87.4	88.0	88.2	88.1	87.8	87.5	88.5
Self-rated health, good (%)	30.3	31.6	29.1	31.5	29.8	31.0	29.3	31.3	29.4	31.6
Individual social network and support variables										
Number of participants	10 676	4699	10 731	5919	13 004	2551	10 081	1808	3193	15 778
Age, year, mean ± SD	75.8 ± 7.1	73.3 ± 5.5	75.9 ± 7.1	73.1 ± 5.6	75.5 ± 6.9	72.3 ± 5	76.1 ± 7.2	73.1 ± 5.3	74.2 ± 5.9	75.1 ± 6.8
Sex, male (%)	37.8	51.4	39.0	45.2	38.2	58.6	37.3	53.3	42.8	41.4
Number of remaining teeth, ≥20 teeth (%)	25.1	36.5	24.0	38.2	26.1	41.4	23.6	38.7	28.3	28.9
Neighborhood educational level, highest (%)	33.5	33.7	31.2	39.7	33.7	37.4	31.7	41.1	34.6	33.1
Education attainment, ≥16 years (%)	4.8	7.2	3.8	9.1	4.8	10.5	3.9	11.3	5.5	5.3
Frequency of toothbrushing, ≥3 times (%)	18.2	20.2	17.0	23.9	18.0	24.4	17.0	23.2	18.3	19.4
Brushing time (minutes), ≥5 min (%)	6.2	6.5	5.7	7.9	6.1	8.2	5.7	8.0	7.7	6.2
Use of dental floss or interdental brushes, yes (%)	10.9	14.9	8.9	20.5	11.4	17.9	9.7	17.3	13.8	11.8
Dental check-up at least once a year, yes (%)	23.0	33.6	21.6	36.3	23.5	38.1	21.5	37.8	28.7	27.2
Frequency of intake of sweet foods, 1–2 times/month	32.2	28.6	32.2	28.4	31.5	28.0	32.2	25.9	38.3	29.0
Smoking status, never (%)	63.2	57.3	62.9	60.4	63.5	53.5	63.8	57.2	56.9	62.1
History of diabetes, no (%)	87.4	88.5	87.2	88.6	87.5	88.4	87.3	88.5	87.8	88.0
Self-rated health, good (%)	26.1	41.0	25.8	40.4	27.5	46.2	25.5	46.3	23.8	32.8

Table 3. Association of remaining teeth with individual- and neighborhood-level variables determined by using multivariable multilevel logistic regression models

Variables		Model 1 OR (95% CI)[a]	Model 1 *P*-value	Model 2 OR (95% CI)[b]	Model 2 *P*-value	Model 3 OR (95% CI)[c]	Model 3 *P*-value
Neighborhood-level variables							
Social capital							
Civic network	Lowest	1.00 (referent)		1.00 (referent)		1.00 (referent)	
	Medium	0.94 (0.85–1.04)	0.224	0.94 (0.85–1.03)	0.180	0.96 (0.87–1.06)	0.399
	Highest	0.87 (0.77–0.98)	0.020	0.94 (0.84–1.04)	0.236	0.99 (0.89–1.10)	0.824
Sports and hobby network	Lowest	1.00 (referent)		1.00 (referent)		1.00 (referent)	
	Medium	1.16 (1.05–1.28)	0.004	1.03 (0.94–1.14)	0.523	1.02 (0.93–1.12)	0.687
	Highest	1.29 (1.16–1.44)	$P < 0.001$	1.06 (0.95–1.18)	0.280	1.04 (0.94–1.16)	0.436
Volunteer network	Lowest	1.00 (referent)		1.00 (referent)		1.00 (referent)	
	Medium	0.95 (0.85–1.06)	0.365	0.95 (0.86–1.05)	0.350	0.96 (0.87–1.06)	0.372
	Highest	0.92 (0.81–1.05)	0.212	0.92 (0.82–1.03)	0.142	0.92 (0.82–1.03)	0.129
Friendship network	Lowest	1.00 (referent)		1.00 (referent)		1.00 (referent)	
	Medium	1.2 (1.08–1.33)	0.001	1.10 (1.00–1.22)	0.061	1.10 (1.00–1.21)	0.057
	Highest	1.37 (1.22–1.54)	$P < 0.001$	1.17 (1.04–1.31)	0.008	1.17 (1.04–1.30)	0.007
Social support	Lowest	1.00 (referent)		1.00 (referent)		1.00 (referent)	
	Medium	1.06 (0.97–1.16)	0.217	1.03 (0.94–1.12)	0.573	1.01 (0.93–1.10)	0.833
	Highest	1.01 (0.86–1.19)	0.904	1.02 (0.93–1.12)	0.657	1.01 (0.92–1.10)	0.885
Neighborhood educational level	Lowest			1.00 (referent)		1.00 (referent)	
	Medium			1.10 (1.01–1.21)	0.039	1.07 (0.98–1.17)	0.132
	Highest			1.22 (1.10–1.35)	$P < 0.001$	1.17 (1.06–1.29)	0.002
Individual-level variables							
Social network							
Civic network	Lowest			1.00 (referent)		1.00 (referent)	
	Medium			1.05 (0.95–1.16)	0.310	1.01 (0.91–1.12)	0.907
	Highest			1.08 (0.98–1.20)	0.123	1.07 (0.97–1.19)	0.187
Sports and hobby network	Lowest			1.00 (referent)		1.00 (referent)	
	Medium			1.07 (0.95–1.20)	0.284	0.99 (0.87–1.12)	0.862
	Highest			1.32 (1.21–1.44)	$P < 0.001$	1.12 (1.02–1.22)	0.019
Volunteer network	Lowest			1.00 (referent)		1.00 (referent)	
	Medium			1.00 (0.90–1.12)	0.930	0.98 (0.88–1.10)	0.788
	Highest			1.13 (1.01–1.27)	0.034	1.09 (0.97–1.23)	0.146
Friendship network	Lowest			1.00 (referent)		1.00 (referent)	
	Medium			1.23 (1.13–1.34)	$P < 0.001$	1.14 (1.04–1.25)	0.004
	Highest			1.23 (1.09–1.40)	0.001	1.14 (0.99–1.30)	0.060
Social support	Lowest			1.00 (referent)		1.00 (referent)	
	Medium			0.93 (0.82–1.05)	0.219	0.93 (0.82–1.05)	0.256
	Highest			1.03 (0.94–1.12)	0.542	1.03 (0.94–1.13)	0.542
Educational attainment	≤9 years			1.00 (referent)		1.00 (referent)	
	10–12 years			1.06 (0.98–1.14)	0.170	0.99 (0.91–1.08)	0.840
	13–15 years			1.14 (1.03–1.26)	0.009	1.04 (0.94–1.15)	0.482
	≥16 years			1.31 (1.14–1.51)	$P < 0.001$	1.12 (0.97–1.30)	0.136
Health behavior							
Daily frequency of toothbrushing	<2 times					1.00 (referent)	
	2 times					1.23 (1.14–1.33)	$P < 0.001$
	3 times≥					0.95 (0.86–1.05)	0.289
Brushing time (minutes)	<3 min					1.00 (referent)	
	3–5 min					1.44 (1.34–1.55)	$P < 0.001$
	5 min ≥					1.81 (1.59–2.05)	$P < 0.001$
Use of dental floss or interdental brushes	No					1.00 (referent)	
	Yes					2.07 (1.88–2.27)	$P < 0.001$
Dental check-up at least once a year	No					1.00 (referent)	
	Yes					1.41 (1.31–1.52)	$P < 0.001$