Table 5. Adjusted hazard ratios (95% confidence intervals) for incident functional disability by combination of exercise and participation in a sport organization.

	N	Crude HR (95% CI)	Adjusted HR (95% CI) Model 1[a)]
Active Participant (AP)	1,888	1.00	1.00
Exercise Alone (EA)	2,548	1.72(1.36–2.18)	1.29(1.02–1.64)
Passive Participant (PP)	447	1.18(0.78–1.80)	1.16(0.76–1.77)
Sedentary (S)	6,698	3.14(2.56–3.85)	1.65(1.33–2.04)

[a)]Model 1 is adjusted for age, sex, annual equivalent income, educational attainment, marital status, occupation status, self-reported medical conditions, depression, smoking, and alcohol consumption.
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The HR of incident functional disability was significantly higher for the "Inactive" groups than the "Exerciser" groups. Regarding participation in a sports organization, the risk of incident functional disability was significantly higher in the "Non-participant" groups compared to the "Participant" groups. Furthermore, the HR was significantly higher for the EA group than the AP group. It was reported that participation in social activities leads to a decrease in the risk of functional decline, [7] and incident disability, [18]. These past studies suggest that one such social activity, participation in a sports organization, may lead to incident functional disability prevention. The results of the present study agreed with this hypothesis. Moreover, the results suggest that the health protection effects of participation in a sports organization include not only the physiological effect of exercise, but other effects aside from the exercise itself. Greater amount of exercise has been shown to lead to decreasing risk of functional disability, [6]. There were about twice as many people in the EA group who exercised every day than in the AP group. As a result, there may have been more positive results from exercise in the EA group. It is possible that this effect led to an apparent decrease in the difference in whether or not subjects participated in a sports organization, causing level of participation to be underestimated. This supports the hypothesis that, even when exercise is performed regularly, incident functional disability may be better prevented if they participate in a sports organization than if they do not. When subjects who participated in a sports organization but responded that they "never" exercised were included in the "S" group for analysis, there was no significant difference between the AP group and the PP group. This suggests that participation in a sports organization may help prevent incident functional disability, regardless of frequency of exercise. It remains unclear, however, why there is a difference in incident functional disability with frequency of exercise in those who participate in a sports organization. Future studies are needed to clarify this point.

Next, we tested to see how far health protection effects from participation in a sports organization aside from the effects of exercise could be explained by social relations. When a measure of social networks was added to the covariates in the model, the HR of the EA group dropped, and significant differences disappeared. Using a method for calculating the rate of change from earlier literature "$(OR_1\text{-}OR_2)/(OR_1\text{-}1)*100$", [20], the decrease in HR by social networks was 6.9%. A decrease by 7.7% was also seen for the S group. Only a small fraction of the change was attributable to social networks, but its involvement was nonetheless indicated. An association has also been shown between social networks and decrease in disability, [11,21]. It is thus conceivable that participation in a sports organization relates more strongly with social networks than private exercise does, and leads to a decrease in incident functional disability. However, the change in HR was minor. In addition, it is possible that social network was not sufficiently evaluated, as frequency of meeting friends was the only measure used.

On the other hand, while social support may also be obtained through participation in a sports organization, adding social support to the covariates had hardly any effect on the HR of the EA group and S group. Group differences in ratio of people with social support were smaller compared to frequency of meeting friends. This suggests that social support has a weaker connection to participation in a sports organization than social networks do. Moreover, in congruence with previous studies, no relationship was seen between incident functional disability and receiving emotional support, [21,22] or providing social support, [11].

Table 6. Adjusted hazard ratios (95% CI) for incident functional disability by social relations.

	Model 1[a)]	Model 2[b)]	Model 3[c)]	Model 4[d)]	Model 5[e)]	Model 6[f)]
Active Participant (AP)	1.00	1.00	1.00	1.00	1.00	1.00
Exercise Alone (EA)	1.29(1.02–1.64)	1.27(1.00–1.61)	1.29(1.02–1.64)	1.29(1.02–1.63)	1.28(1.01–1.63)	1.30(1.03–1.65)
Passive Participant (PP)	1.16(0.76–1.77)	1.15(0.76–1.76)	1.15(0.75–1.75)	1.15(0.76–1.75)	1.14(0.75–1.74)	1.18(0.77–1.79)
Sedentary (S)	1.65(1.33–2.04)	1.60(1.29–1.98)	1.64(1.33–2.03)	1.63(1.32–2.02)	1.63(1.32–2.02)	1.64(1.33–2.03)

[a)]Model 1 is adjusted for age, sex, annual equivalent income, educational attainment, marital status, occupation status, self-reported medical conditions, depression, smoking, and alcohol consumption.
[b)]Model 2 is adjusted for the covariates in Model 1 plus frequency of meeting friends.
[c)]Model 3 is adjusted for the covariates in Model 1 plus receiving emotional support.
[d)]Model 4 is adjusted for the covariates in Model 1 plus providing emotional support.
[e)]Model 5 is adjusted for the covariates in Model 1 plus receiving instrumental support.
[f)]Model 6 is adjusted for the covariates in Model 1 plus providing instrumental support.
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These findings suggest that social support does not explain why participation in a sports organization leads to a decrease in incident functional disability.

The present study has four limitations. The first is that, for people participating in a sports organization, there is no distinction between exercise carried out in the sports organization and private exercise, nor is there any clear distinction among the types of exercise. We acknowledge that people in the "Exercise Alone" category are not necessarily exercising in solitude. Instead, we have used this label to contrast it with people who exercise as part of an organized activity. In future studies, a question should be added to the questionnaires that will enable such distinction. The second limitation is that final analysis was only carried out on about 40% of subjects due to lack of response to the questionnaires and missing variables; therefore it is possible that the results of the present study do not give a complete picture of the region studied. The third limitation is that the sample size in the present study was too small to allow for more detailed analysis of frequency of exercise. Future studies are required to further elucidate the reason why incident functional disability prevention efficacy was greater in the AP group than the EA group and clarify the most preferable frequency of exercise. The fourth limitation is that the only measure used was frequency of meeting friends, though social networks were used to test which aspect of participation in a sports organization serves to prevent incident functional disability. Future studies should consider more aspects of social networks.

In conclusion, tests of the relationship between incident functional disability and 4 groups made up of different combinations of performance of exercise and participation in a sports organization showed a significantly higher HR in the EA group compared to the AP group. This suggests that, even when exercise is performed once a week or more, incident functional disability may be better prevented if the person participates in a sports organization than if they do not. Moreover, when various aspects of social relations were added to the covariates, only inclusion of social networks brought a small reduction in the HR of the EA group and S group. Compared to private exercise, participation in a sports organization correlates more with social networks, which may lead to a small decrease in incident functional disability.

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Author Contributions

Conceived and designed the experiments: SK YK KK IK. Analyzed the data: SK YK KK YI. Wrote the paper: SK YK KK IK. Reviewing of manuscript: SK YK KK HH YI KS IK. Acquisition of data: KK HH KS.

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Dental status and incident falls among older Japanese: a prospective cohort study

Tatsuo Yamamoto,[1] Katsunori Kondo,[2] Jimpei Misawa,[2] Hiroshi Hirai,[3] Miyo Nakade,[4] Jun Aida,[5] Naoki Kondo,[6] Ichiro Kawachi,[7] Yukio Hirata[1]

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For numbered affiliations see end of article.

Correspondence to
Dr Yukio Hirata;
hiratay@kdcnet.ac.jp

ABSTRACT

Objective: To examine if self-reported number of teeth, denture use and chewing ability are associated with incident falls.

Design: Longitudinal cohort study (the Aichi Gerontological Evaluation Study).

Setting: 5 Japanese municipalities.

Participants: 1763 community-dwelling individuals aged 65 years and older without experience of falls within the previous year at baseline.

Main outcome measures: Self-reported history of multiple falls during the past year at the follow-up survey about 3 years later. Baseline data on the number of teeth present and/or denture use and chewing ability were collected using self-administered questionnaires. Logistic regression analyses controlled for sex, age, functional disability during follow-up period, depression, self-rated health and educational attainment.

Results: 86 (4.9%) subjects reported falls at the follow-up survey. Logistic regression models fully adjusted for all covariates showed that subjects having 19 or fewer teeth but not using dentures had a significantly increased risk for incident falls (OR 2.50, 95% CI 1.21 to 5.17, p=0.013) compared with those having 20 or more teeth. Among subjects with 19 or fewer teeth, their risk of falls was not significantly elevated so long as they wore dentures (OR 1.36, 95% CI 0.76 to 2.45, p=0.299). No significant association was observed between chewing ability and incident falls in the fully adjusted model.

Conclusions: Having 19 or fewer teeth but not using dentures was associated with higher risk for the incident falls in older Japanese even after adjustment for multiple covariates. Dental care to prevent tooth loss and denture treatment for older people might prevent falls, although the authors cannot exclude the possibility that the association is due to residual confounding.

ARTICLE SUMMARY

Article focus
- An association has been reported between dental occlusion and physical function including lower extremity dynamic strength and balance.
- Whether number of teeth, denture use and chewing ability predict subsequent incidence of falls is unknown.
- The aim of this study was to examine if self-reported number of teeth, denture use and chewing ability are associated with incident falls.

Key messages
- Having 19 or fewer teeth but not using dentures was a strong independent predictor of incident falls in a community-dwelling older population.
- In addition to preventing tooth loss, denture treatment for older people might prevent falls.

Strengths and limitations of this study
- Strengths of this study include large sample size, population-based sampling and control for many potential confounding factors.
- The following limitations should be considered: the information on dental status and falls was self-reported and misclassification of cases is possible. Moreover, we cannot exclude the possibility that the association is due to residual confounding.

INTRODUCTION

Falls occur frequently in older people and adversely affect their quality of life. More than one-third of persons aged 60 years and older fall each year in Japan,[1] England[2] and the USA,[3] and in half of cases, falls are recurrent.[3] The consequences of falls are severe: 6% of falls lead to a fracture and 24% lead to other serious injuries.[2] Thus, falls impose a burden on the sustainability of health and long-term care in Japan and many other countries, where population is rapidly ageing.[4] In Japan, the annual health and long-term care costs attributable to falls are about 730 thousand million Japanese yen in 2002, which amounts to roughly 5% of the entire health and long-term care costs.[5]

A number of studies[6] including those using Japanese data[7] have identified risk factors for falls, including female sex, older age, having a history of falls, arthritis, cerebrovascular disease, depression and the impairment of muscle strength and/or balance. Although exercise programmes including balance training are effective,[8] multifactorial fall prevention programmes to address these risk factors have not been successful in reducing falls.[9] A recent systematic review concluded that there is limited evidence to suggest that multifactorial fall prevention programmes in primary care, community or emergency care settings are effective in reducing the number of falls.[10] Therefore, identification of additional modifiable risk factors may be helpful to establish more effective programmes for fall prevention.

Unhealthy dental status is a candidate risk factor for falls.[11 12] A longitudinal study showed that partial or complete loss of dental occlusion was associated with a decline in lower extremity dynamic strength and balance function.[13] One 1-year prospective longitudinal study using 146 demented older people reported the association between dental occlusion and subsequent physical health.[14] Researchers have argued that these potential links between dental health and physical health may be because jaw position affects body posture.[11] Proprioceptive receptors of the masticatory muscular system and dentoalveolar ligaments provide sensory afferent input,[15] and hence poor dental occlusion may decrease that proprioception, thereby interfering with the stability of head posture (and increasing the risk of falling). However, whether or not dental occlusion and chewing ability actually predict the subsequent incidence of falls is largely unknown.

Therefore, this prospective study aimed to determine the association between dental health in terms of the number of teeth present, denture use and chewing ability and the incidence of falls in a large cohort of older Japanese people.

METHODS

Study population

Our analyses were based on data from the Aichi Gerontological Evaluation Study (AGES) Project, an ongoing Japanese prospective cohort study.[16 17] The detailed protocol of the AGES and baseline characteristics of the study participants have been published elsewhere.[16 18] In brief, the AGES aims to investigate the factors related to the loss of healthy years, such as functional decline, cognitive impairment or death among non-institutionalised older people. The sample was restricted to those who did not already have a physical or cognitive disability at baseline, defined by not receiving public long-term care insurance benefits and self-reported dependence in walking, toileting and bathing.

The sampling frame for the AGES cohort was selected as follows. In 2003, the residential registers of five municipalities in Aichi prefecture were obtained with the cooperation of city officials. From these comprehensive registers, we selected a random sample of one in three citizens aged 65 years or older in four towns (1281, 1537, 1766 and 1873) and a random sample of 1666 in a city. They (N=8123) were then mailed the baseline questionnaire, inviting them to participate in the AGES cohort study. Responses were obtained from 3998 subjects (49.2%), and 3981 subjects were identified using ID. We mailed a follow-up survey between March 2006 and March 2007 to the 3471 subjects after excluding 510 subjects who died or started receiving insurance benefits due to certified disability (N=472) or could not be traced (N=38). Two thousand six hundred and forty subjects responded to the follow-up survey (76.1%) and formed the analytic sample for our study. After excluding 166 and 545 subjects who experienced multiple and single falls, respectively, as well as 106 subjects without information of falls at baseline, we were left with 1823 subjects who did not report experiencing falls at baseline. After excluding 56 subjects without information on falls at follow-up and four subjects without information on age, a total of 1763 subjects formed the final analytic population of this study. The AGES protocol was reviewed and approved by the Ethics Committee on Research of Human Subjects at Nihon Fukushi University.

Outcome variables

History of falls was ascertained by asking, "Have you had any falls over the past year?" with possible answers of "multiple times," "once" or "none." Multiple falls was used as an outcome and the last two categories were combined because previous studies have found that single fallers are more similar to non-fallers than to recurrent fallers on a range of medical, physical and psychological risk factors.[3 19 20]

Dental health variables

Dental status and chewing ability were assessed using a self-administered questionnaire. Respondents were asked to classify their dental status as having 20 or more teeth, having 19 or fewer teeth with dentures, having 19 or fewer teeth without dentures, having few teeth with dentures or having few teeth without dentures. Data from having 19 or fewer teeth with dentures and those from having few teeth with dentures were combined. Data from having 19 or fewer teeth without dentures and those from having few teeth without dentures were also combined.

Chewing ability was ascertained by asking, "How is your ability to chew?" with possible answers being "I can chew anything I want," "I can chew most foods with some exceptions," "I can eat limited foods as I cannot chew very well," "I can hardly chew anything" and "I have liquid foods as I cannot chew at all." Data from the last three categories were combined due to the small number of respondents.

Covariates

Studies suggest that falls are associated with sex,[7 21] age,[2 7] stroke,[7] severe foot problems,[2] impaired vision and impaired hearing,[2] activities of daily living (ADL),[3 6 21] body mass index (BMI),[21] use of sedatives,[2] depression,[2] self-rated health,[21] exercise,[2] mobility[2] and socioeconomic status.[22] Therefore, associations of incident fall with sex, age, present illness related to falls, ADL, BMI, use of sedatives, depression, self-rated health, exercise (how much they walked in minutes per day), frequency of outings, educational attainment and equivalised household income were analysed. Self-reported current medical treatment of stroke, osteoporosis, joint disease/ neuralgia, injury/ fracture, impaired vision and/ or impaired hearing was used as a variable for present illness related to falls. To evaluate functional status, the survey asked whether the respondents had difficulty or needed someone's assistance in performing any of the following ADL: basing, walking and using the toilet.[23] Subjects without difficulty for all three ADL items were categorised into ADL without limitation and those with at least one ADL item with difficulty into ADL with limitation. BMI was categorised into three groups (<18.5, 18.5e 24.9 and 25.0 or more).[24] Depression was assessed with the short version of the Geriatric Depression Scale-15 developed for self-administration in the community using a simple yes/ no format[25] and was categorised into three groups: 0e 4 (no), 5e 9 (mild) and 10e 15 (moderate to severe). To adjust household income for household size, equivalised income was calculated by dividing the household income by the square root of the number of household members and grouped into one of the seven categories. In addition to these covariates, data on functional disability during follow-up period were collected from the public long-term care insurance database maintained by each participating municipality and used as a covariate. Incidence of functional disability was determined based on when a person newly qualified for the insurance benefit, new registrations to the public long-term care insurance database.[26] The distribution of each covariate at baseline for the overall AGES 2003 cohort (n=32 891) has been reported elsewhere.[16]

Statistical analysis

Categorical variables that included missing data were recorded by reassigning missing values to separate "missing" categories in order to maximise the number of subjects included in the statistical analysis and thereby maximise statistical power. Logistic regression models were used to calculate the ORs and 95% CIs for the incident falls at the follow-up. First, univariate ORs were calculated for each dental health variable and each covariate. Variables that were marginally significant ($p<0.10$) in the univariate analyses were selected as covariates for subsequent multivariate analysis. Then, logistic regression analysis was performed for each dental variable after including sex, age, functional disability during follow-up period, depression, self-rated health and educational attainment as covariates. All statistical analyses were conducted using IBM SPSS Statistics V.19 (IBM Co.).

RESULTS

A total of 86 (4.9%) of the 1763 respondents reported the incidence of multiple falls at the follow-up survey. Table 1 shows the rates of fallers and non-adjusted ORs for reporting multiple falls at the follow-up survey according to dental health variables and covariates. Univariate models showed that poor dental status, chewing ability, male sex, older age, lower functional disability during follow-up period, depression, poor self-rated health and low educational attainment were each associated with incident falls.

In the fully adjusted model, subjects with 19 or fewer teeth without dentures had a 2.50 (95% CI 1.21 to 5.17)-fold increased risk for incident falls compared with those having 20 or more teeth(Table 2). No significant association was observed between incident falls and chewing ability after adding all covariates in the logistic regression model. When the two dental health variables were entered simultaneously into the same model with full adjustment for all covariates, there was no change in the ORs for any of the dental status variables.

DISCUSSION

Results of the present study showed that subjects with 19 or fewer teeth without dentures had a significantly higher risk for incident falls than those with 20 or more teeth, even after adjusting for multiple potential confounding factors including demographics, physical and mental health status, and socioeconomic status. These findings are consistent with those of a 1-year longitudinal study using 146 older patients with severe dementia, showing that patients with functionally inadequate dental status had significantly more frequent falls than those with functionally adequate occlusion composed of natural teeth, dentures or both.[14] Interestingly, among subjects with 19 or fewer teeth, their risk of falls was not significantly elevated so long as they wore dentures. These results suggest that the poor dental occlusion due to not using dentures after losing teeth is a strong risk factor for falls among subjects with 19 or fewer teeth.

There are several possible pathways between not using dentures after losing teeth and incident falls. One possibility is that the loss of occlusion due to not using dentures may result in a decrease in functional balance and these functional declines lead to falls. A cross-sectional study suggests that dental occlusal condition is associated with balance function.[12] An 8-year longitudinal study showed that partial or complete loss of occlusion was associated with a decrease in balance function.[13] Because balance deficit is a well-known risk factor for falls,[6] it is plausible that poor balance may explain the increased risk of falls among subjects with poor dental occlusion.

A clinical study showed that dental occlusion affects postural and gaze stabilisation because proprioceptive receptors of the masticatory muscular system and dentoalveolar ligaments provide sensory afferent input,

Table 1 Univariate associations of dental health variables and covariates with incident falls

	Total n	Fallers n (%)	OR (95% CI)	p Value
Dental status				
$ 20 teeth	586	17 (2.9)	1.00	
# 19 teeth with dentures	958	49 (5.1)	1.80 (1.03 to 3.16)	0.039
# 19 teeth without dentures	198	17 (8.6)	3.14 (1.57 to 6.28)	0.001
Missing	21	3 (14.3)	5.58 (1.50 to 20.76)	0.010
Chewing ability				
Can chew anything	719	30 (4.2)	1.00	
Can chew most foods	935	47 (5.0)	1.22 (0.76 to 1.94)	0.414
Cannot chew very well	97	9 (9.3)	2.35 (1.08 to 5.11)	0.031
Missing	12	0 (0.0)	0.00 (0.00)	0.999
Sex				
Female	853	32 (3.8)	1.00	
Male	910	54 (5.9)	1.62 (1.03 to 2.53)	0.035
Age (years)				
65e 69	707	23 (3.3)	1.00	
70e 74	569	27 (4.7)	1.48 (0.84 to 2.61)	0.175
75e 79	325	18 (5.5)	1.74 (0.93 to 3.28)	0.084
80e 84	120	12 (10.0)	3.30 (1.60 to 6.84)	0.001
$ 85	42	6 (14.3)	4.96 (1.90 to 12.93)	0.001
Present illness related to falls*				
No	1224	58 (4.7)	1.00	
Yes	539	28 (5.2)	1.10 (0.69 to 1.75)	0.682
Activities of daily living				
Without limitation	1669	81 (4.9)	1.00	
With limitation or missing	94	5 (5.3)	1.10 (0.44 to 2.79)	0.838
Functional disability during follow-up period				
No	1734	81 (4.7)	1.00	
Yes	29	5 (17.2)	4.25 (1.58 to 11.43)	0.004
Body mass index				
<18.5	113	8 (7.1)	1.68 (0.78 to 3.62)	0.189
18.5e 24.9	1196	52 (4.3)	1.00	
$ 25.0	380	21 (5.5)	1.29 (0.77 to 2.17)	0.342
Missing	74	5 (6.8)	1.59 (0.62 to 4.12)	0.336
Use of sedatives				
No	1602	80 (5.0)	1.00	
Yes	161	6 (3.7)	0.74 (0.32 to 1.72)	0.478
Depression				
No	1143	39 (3.4)	1.00	
Mild	311	21 (6.8)	2.05 (1.19 to 3.54)	0.010
Moderate to severe	77	8 (10.4)	3.28 (1.48 to 7.29)	0.004
Missing	232	18 (7.8)	2.38 (1.34 to 4.24)	0.003
Self-rated health				
Excellent	162	6 (3.7)	1.00	
Good	1192	50 (4.2)	1.14 (0.48 to 2.70)	0.769
Fair	321	21 (6.5)	1.82 (0.72 to 4.60)	0.206
Poor	59	9 (15.3)	4.68 (1.59 to 13.80)	0.005
Missing	29	0 (0.0)	0.00 (0.00)	0.998
Exercise (walk in minute/day)				
$ 60	430	20 (4.7)	1.00	
30e 59	569	16 (2.8)	0.59 (0.30 to 1.16)	0.126
<30	564	38 (6.7)	1.48 (0.85 to 2.58)	0.167
Missing	200	12 (6.0)	1.31 (0.63 to 2.73)	0.474
Frequency of outings				
Almost everyday	843	37 (4.4)	1.00	
2e 3 times a week	532	27 (5.1)	1.17 (0.70 to 1.94)	0.557
Once a week or less	335	20 (6.0)	1.38 (0.79 to 2.42)	0.256
Missing	53	2 (3.8)	0.85 (0.20 to 3.65)	0.831

Continued

Table 1 Continued

	Total n	Fallers n (%)	OR (95% CI)	p Value
Educational attainment (years)				
$ 13	184	4 (2.2)	1.00	
10e 12	506	23 (4.5)	2.14 (0.73 to 6.28)	0.165
6e 9	953	49 (5.1)	2.44 (0.87 to 6.84)	0.090
<6	53	4 (7.5)	3.67 (0.89 to 15.22)	0.073
Missing	67	6 (9.0)	4.43 (1.21 to 16.21)	0.025
Equivalised household income (yen)				
<500 000	53	0 (0.0)	0.00 (0.00)	0.997
500 000e 999 999	108	7 (6.5)	1.00	
1 000 000e 1 499 999	139	7 (5.0)	0.77 (0.26 to 2.25)	0.627
1500 000e 1 999 999	262	15 (5.7)	0.88 (0.35 to 2.21)	0.780
2000 000e 2 999 999	429	16 (3.7)	0.56 (0.22 to 1.39)	0.213
3000 000e 3 999 999	263	15 (5.7)	0.87 (0.35 to 2.20)	0.773
$ 4000 000	164	5 (3.0)	0.45 (0.14 to 1.47)	0.187
Missing	345	21 (6.1)	0.94 (0.39 to 2.26)	0.882

*Stroke, osteoporosis, joint disease/neuralgia, injury/fracture, impaired vision and/or impaired hearing.

and hence poor dental occlusion may decrease that proprioception and interfere with the stability of head posture.[15] Another clinical study showed that denture use improves postural swaying.[27] Because using dentures reduced the OR for incident falls in the present study, proprioceptive receptors of the masticatory muscular system might be more strongly associated with balance function and falls than those of dentoalveolar ligaments.

Some subjects with 20 or more teeth may have had dentures in the present study; however, the information was not obtained. Subjects with 20 or more teeth without dentures may be more appropriate than those with 20 or more teeth with/ without dentures as a reference, and lack of the information might underestimate the association between dental status and incident falls. However, studies show that people having at least 20 teeth usually can eat anything even they do not ware dentures.[28 29] Therefore, the lack of the information of with/ without dentures in subjects having 20 or more teeth may be negligible.

We excluded individuals with history of falls because we wanted to examine prospectively the risk of incident falls. In addition, there is a theoretical possibility that history of falls might confound the association between number of teeth and risk of future falls, that is, history of falls in the past can be a prior common cause of (1) number of teeth (because some people may break teeth when they fall) and (2) past falls predict future falls. For these reasons, we felt that it was justified to exclude those with fall history at baseline.

In the present study, self-reported chewing ability was not associated with the incident falls. This result disagreed with those from a cross-sectional study showing a significant association between chewing ability judged from number of foods chewable and one-leg standing time.[30] Because self-reported mastication can be modified by cooking (eg, cooking soft meal helps chewing ability) and is more subjective than self-reported number of teeth present and denture use, this might dilute the association between self-reported chewing ability and the incident falls. A study using 5643 subjects aged 40e 89 years showed that number of functional teeth which differentiate subjects with and without subjective dysphagia, defined as suffering any kind of subjective impairment to eating function, including biting difficulty, declined with age.[31] Additional studies using objective measures for chewing ability are required to clarify the relationship between chewing ability and the incident falls.

Using dentures does not always recover chewing ability. For example, a cross-sectional study showed that biting forces among removable partial and complete denture wearers were 35% and 11%, respectively, when expressed as a percentage of the subjects with natural dentition.[32] These results may explain the different associations of dental status and chewing ability with incident falls in the present study. When both dental status and chewing ability were simultaneously entered in the fully adjusted logistic regression model in the present study, only dental status was still significantly associated with incident falls.

Men were at increased risk of falls in the present study, which disagrees with a meta-analysis[7] based on people aged 60 years or older showing that female sex was a risk factor. On the other hand, our study result is also similar to another large study of 12 684 individuals aged 85 years or older.[21] We feel that the association between sex and risk of falls might vary according to the study population. Indeed, current clinical guidelines for the prevention of falls do not include sex as a risk factor,[6 33] and thus it may not be a settled question.

Strengths and limitations

We note some strength of the present study including large sample size, population-based sampling and

Table 2 Multivariate adjusted OR and 95% CI for the association of dental status and chewing ability with incident falls

	OR (95% CI)	p Value	OR (95% CI)	p Value
Dental status				
$ 20 teeth	1.00			
# 19 teeth with dentures	1.36 (0.76 to 2.45)	0.299		
# 19 teeth without dentures	2.50 (1.21 to 5.17)	0.013		
Missing	5.75 (1.23 to 26.78)	0.026		
Chewing ability				
Can chew anything			1.00	
Can chew most foods			0.97 (0.59 to 1.59)	0.910
Cannot chew very well			1.47 (0.64 to 3.37)	0.361
Missing			0.00 (0.00)	0.999
Sex				
Female	1.00		1.00	
Male	1.86 (1.16 to 2.96)	0.010	1.86 (1.16 to 2.96)	0.009
Age (years)				
65e 69	1.00		1.00	
70e 74	1.31 (0.73 to 2.34)	0.366	1.36 (0.76 to 2.42)	0.302
75e 79	1.42 (0.74 to 2.74)	0.290	1.57 (0.82 to 3.02)	0.178
80e 84	2.51 (1.17 to 5.39)	0.018	2.84 (1.34 to 6.04)	0.007
$ 85	3.78 (1.27 to 11.19)	0.017	4.63 (1.59 to 13.49)	0.005
Functional disability during follow-up period				
No	1.00		1.00	
Yes	2.30 (0.75 to 7.06)	0.144	2.11 (0.70 to 6.37)	0.184
Depression				
No	1.00		1.00	
Mild	1.82 (1.01 to 3.26)	0.046	1.82 (1.01 to 3.26)	0.045
Moderate to severe	2.47 (1.02 to 5.97)	0.045	2.49 (1.03 to 6.02)	0.042
Missing	2.14 (1.09 to 4.17)	0.026	2.07 (1.06 to 4.04)	0.032
Self-rated health				
Excellent	1.00		1.00	
Good	1.14 (0.47 to 2.77)	0.767	1.07 (0.44 to 2.59)	0.877
Fair	1.43 (0.54 to 3.78)	0.474	1.33 (0.50 to 3.54)	0.568
Poor	2.71 (0.83 to 8.77)	0.097	2.60 (0.81 to 8.34)	0.109
Missing	0.00 (0.00)	0.998	0.00 (0.00)	0.998
Educational attainment (years)				
$ 13	1.00		1.00	
10e 12	2.49 (0.83 to 7.45)	0.102	2.59 (0.87 to 7.72)	0.089
6e 9	2.21 (0.77 to 6.33)	0.140	2.50 (0.87 to 7.12)	0.087
<6	1.77 (0.37 to 8.56)	0.476	2.24 (0.49 to 10.27)	0.299
Missing	2.78 (0.68 to 11.38)	0.156	3.17 (0.77 to 13.01)	0.110

control for many potential confounding factors. However, the present study has a number of limitations. First, measurement of dental status was based on self-report, not based on clinical examination. However, the validity and reliability of self-reported number of teeth has been established by multiple studies and widely used in epidemiological surveys.[34] For example, validation studies in the USA and Japan have reported a high agreement between self-reported and examined number of teeth (Pearson's correlation coefficient: r=0.97 and 0.93, respectively) in 50 community-dwelling individuals aged 70 years or older and 2496 subjects with a mean age of 59.[35] [36] Second, self-report of falls may not be perfectly accurate.[37] However, the associations with demographic factors and other covariates are in the generally expected direction, suggesting that there may be sufficient value in this outcome.

CONCLUSIONS

The primary implication of this study is the importance of maintaining the dental occlusion, especially with natural teeth, in order to prevent falls among older adults. The loss of teeth might be an independent risk factor for incident falls, but it could be prevented by using dentures. Promoting dental care including proper use of denture might be an additional option for the prevention of falls in addition to current interventions targeting conventional risk factors, which warrants further interventional studies testing the effects of dental care and denture use on the prevention of falls.

Author affiliations
[1]Division of Sociological Approach in Dentistry, Department of Dental Sociology, Kanagawa Dental College, Yokosuka-shi, Kanagawa, Japan
[2]Center for Well-being and Society, Nihon Fukushi University, Nagoya-shi, Aichi, Japan

[3]Department of Civil and Environmental Engineering, Faculty of Engineering, Iwate University, Morioka-shi, Iwate, Japan
[4]Department of Nutrition, Faculty of Health and Nutrition, Tokaigakuen University, Nagoya-shi, Aichi, Japan
[5]Department of International and Community Oral Health, Tohoku University Graduate School of Dentistry, Sendai-shi, Miyagi, Japan
[6]Department of Health Sciences, Interdisciplinary Graduate School of Medicine and Engineering, University of Yamanashi, Chuo-shi, Yamanashi, Japan
[7]Department of Society, Human Development and Health, Harvard School of Public Health, Boston, Massachusetts, USA

Contributors TY and YH had the idea for the study, participated in its design, performed the statistical analysis and drafted the manuscript, and YH is the guarantor. KK is coordinator of Aichi Gerontological Evaluation Study Project, helped develop the idea of the study, participated in acquiring the data and with design and edited the manuscript. JM participated in design of study and edited the manuscript. HH and MN participated in acquiring the data and with design and critically revised the manuscript. JA, NK and IK participated in the design of the study, deciding on statistical methods used, helped in interpreting the results and revising the manuscript.

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Dental status and incident falls among older Japanese: a prospective cohort study

Tatsuo Yamamoto, Katsunori Kondo, Jimpei Misawa, et al.

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Gender differences on the impacts of social exclusion on mortality among older Japanese: AGES cohort study

Masashige Saito [a,*], Naoki Kondo [b], Katsunori Kondo [c], Toshiyuki Ojima [d], Hiroshi Hirai [e]

[a] Department of Social Welfare, Nihon Fukushi University, Okuda, Mihama-cho, Chita-gun, Aichi-pref 470-3295, Japan
[b] Department of Health Economics and Epidemiology Research, Graduate School of Medicine, The University of Tokyo, Japan
[c] Center for Well-being and Society, Nihon Fukushi University, Japan
[d] Department of Community Health and Preventive Medicine, Hamamatsu University School of Medicine, Japan
[e] Department of Civil Environmental Engineering, Iwate University, Japan

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abstract

To evaluate the gender-specific impact of social exclusion on the mortality of older Japanese adults, we performed a prospective data analysis using the data of the Aichi Gerontological Evaluation Study (AGES). In AGES, we surveyed functionally independent residents aged 65 years or older who lived in six municipalities in Aichi prefecture, Japan. We gathered baseline information from 13,310 respondents in 2003. Information on mortality was obtained from municipal databases of the public long-term care insurance system. All participants were followed for up to 4 years. We evaluated social exclusion in terms of the combination of social isolation, social inactivity, and relative poverty. Cox's proportional hazard model revealed that socially excluded older people were at significantly increased risk (9e 34%) for premature mortality. Those with simultaneously relative poverty and social isolation and/or social inactivity were 1.29 times more likely to die prematurely than those who were not socially excluded. Women showed stronger overall impact of social exclusion on mortality, whereas relative poverty was significantly associated with mortality risks for men. If these associations are truly causal, social exclusion is attributable to 9000e 44,000 premature deaths (1e 5%) annually for the older Japanese population. Health and social policies to mitigate the issue of social exclusion among older adults may require gender-specific approaches.

Introduction

There is a growing interest in the concept of social exclusion. Social exclusion is closely associated with material deprivation due to poverty but it covers wider and dynamic dimensions, including deprivation in social networks, living arrangements, goods, employment, access to benefits, and cultural capitals (Berghman, 1995). Social exclusion is a "multidimensional" problem and a "dynamic process", whereas the traditional concept of poverty focuses on "income" and "static outcome". As shown in Table 1, various methods for measuring social exclusion exist. Barnes (2002) emphasized the importance of measuring the dimensions of interpersonal relationships and social participation. As Barnes argued, because "poverty is not simply about income, but about a lack of resources that impedes participation in society, measuring poverty requires detailed analysis of multiple deprivation and participation issues. Social exclusion focuses more on relational issues; in other words, inadequate social participation, lack of social integration and lack of power." Note that the term "social exclusion" has been used in a different context in social psychology. Specifically, the negative consequence of unfavorable interpersonal relationships (e.g., being rejected by one's peers) is similar to other concepts, such as social rejection and social ostracism (Baumeister, DeWall, Ciarocco, & Twenge, 2005; Nolan, Flynn, & Garber, 2003; Williams, Forgas, & von Hippel, 2005).

The World Health Organization has mentioned that "Poverty, relative deprivation and social exclusion have a major impact on health and premature death" (Wilkinson & Marmot, 2003). In fact, there are a large number of studies that focus on specific dimensions of social exclusion and health, for example, relative poverty, socioeconomic inequality, and neighborhood relationships (Kawachi, 2000; Kondo, Kawachi, Subramanian, Takeda, & Yamagata, 2008; Kondo, Sembajwe, et al., 2009; Leclerc, Chastang, Menvielle, & Luce, 2006). However, there are few studies that have analyzed the impact of accumulation of poverty and social disintegration. It is highly likely that an individual's experiences overlap in multiple dimensions of social exclusion, and we should

* Corresponding author.
E-mail address: masa-s@n-fukushi.ac.jp (M. Saito).

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Table 1
Existing indices/measures of social exclusion.

Study	Domain (Dimension)	
European Commission (2002) "non-monetary indicators from EUROSTAT"	(1) Enforced lack of desired possessions (2) Absence of basic housing facilities (3) Problems with accommodation and the environment (4) Lack of ability to afford most basic requirements (5) Inability to meet payment schedules	
Bradshaw, Williams, and Levitas (2000)	(1) Poverty / Lack of socially perceived necessities (2) Exclusion from the labor market (3) Service excluded (4) Exclusion from social relations	
Burchardt, Grand, and Piachaud (2002)	(1) Consumption (2) Production	(3) Political engagement (4) Social interaction
Choffe (2001)	(1) Income exclusion (2) Employment (3) Housing	(4) Health (5) Family exclusion (6) Cultural exclusion
Percy-Smith (2000)	(1) Economic (2) Social (3) Political (4) Neighborhood	(5) Individual (6) Spatial (7) Group
Tsakloglou (2003)	(1) Poverty (2) Amenities deprivation	(3) Durables deprivation (4) Necessities deprivation

focus on the overall impact of status for socially excluded individuals rather than the individual impact of each specific dimension. Scharf, Phillipson, and Smith (2004) conducted a cross-sectional survey in three socially deprived areas, and observed that older people who experienced multiple forms of social exclusion were significantly likely to rate their quality of life as poor or very poor. To our knowledge, there has been no large-scale cohort research that has assessed the relative and attributable impact of social exclusion on health among older Asian people. In addition, gender differences have not been well studied.

The issue of social exclusion may be of particular importance in Japan, where the population is currently the oldest in the world (Ikeda et al., 2011; United Nations, 2001). Older persons are likely to be financially vulnerable and at risk for being isolated (O'Rand, 1996). The Japanese government has recognized that 25% of older (aged 65 years or more) citizens live below the official poverty line, whereas the proportion is 16.0% among the general population (Cabinet Office of Japan, 2010a, 2010b). This is not a small proportion for a developed country (MHLW, 2011; OECD, 2005, 2011). However, social exclusion and other key socioeconomic determinants of health are rarely applied in health and social policy in Japan. The purpose of this study was to evaluate the relative and attributable impact of social exclusion on mortality among older Japanese adults.

Methods

Study subjects

We used data from a prospective Japanese cohort study, the Aichi Gerontological Evaluation Study (AGES). AGES was a mail survey of 29,374 people aged 65 or older who were randomly selected from the older residents of six municipalities in the Chita peninsula, Aichi prefecture, Japan (Kondo, 2010; Nishi, Kondo, Hirai, & Kawachi, 2011). Baseline information was gathered in 2003, with a response rate of 50.4% ($n = 14,804$). We used baseline data from 13,310 functionally independent respondents who did not have any problems with activities of daily living in terms of walking, toileting, and bathing. Information on mortality was obtained from the database of the public long-term care insurance system, which is run by the municipal government. The mean age of participants was 72.8 years ($SD = 5.8$), and 51.1% were women. Our study protocol and questionnaire procedure were approved by the Ethics Committee in Research of Human Subjects at Nihon Fukushi University. Written informed consent was assumed by voluntary return of the questionnaire.

Measurements

Evaluation of social exclusion

We used relative poverty, social isolation, and social inactivity due to inevitable reasons to measure social exclusion. Relative poverty was defined as below half of the median annual income; the threshold was 1.13 million Japanese yen. This definition of relative poverty was originally from OECD, which conceptually relies on the relative approach of the Luxembourg Income Study (Forster, 1994). We used annual household pre-tax income. For each response, we equivalized household income for household size, dividing income by the square root of the number of household members.

Townsend (1963) defined isolation as "having few contacts with family and community." In this study, we evaluated both face-to-face and non-face-to-face contacts using the following questions; "How often do you see your family members or relatives who are living apart?" and "How often do you make contact with your family members or relatives who are living apart by letter, telephone, or email?" We included six response options for the frequency of contact, ranging from "almost everyday" to "almost never." We also asked the same questions for contact with close friends. Respondents who selected "one or two times per month" or less with both relatives and close friends were considered as being "isolated."

Socially inactive people could be socially excluded, if they are inactive for inevitable reasons, which are reasons that are not easily changed by oneself or of personal choice. Our question about hobbies/activities included eight types of activities: sports, cultural, music, creative, horticulture, watching TV, traveling, and stock investments. For respondents who answered "no hobby", we asked about reasons for lack of participation in any hobbies/activities. Response options were: 1. "I don't have enough motivation," 2. "I discontinued for some reason," 3. "I cannot find anything interesting," 4. "I feel it troublesome to associate with people," 5. "I don't have enough money," 6. "I don't have enough time," 7. "I've had no opportunities," and 8. "Other." Respondents were recognized as having "no hobby due to inevitable reasons" if they selected options 5 or 7, because "no opportunity" and "no money" were clearly not based on individual choice. Although other options may also be inevitable reasons in certain contexts, we did not use these options in order to eliminate any possibility of nonparticipation due to personal choice. For example, those who selected option 2 and/or 6 may have discontinued their hobby or activity because they had other social obligations other than the hobby or activity (e.g. job or volunteer work).

According to these evaluations, we grouped our study participants into four categories: (a) not socially excluded, (b) living in relative poverty, (c) socially isolated and/or socially inactive, and (d) living in relative poverty and socially isolated/inactive. We created these groups because social exclusion was a broader or extended concept of income/material poverty. In creating these groupings, we sought to evaluate the differential impact of "poverty" and extended "isolation and inactivity", as well as the overall impact of social exclusion.

In fact, the questions we used represented only three dimensions despite the existence of many phrases to explain the potential dimensions of social exclusion (see Table 1); however, our three questions represented the potential dimensions used in previous studies. Based on our theoretical reviews, we found that the dimensions of social exclusion used in preceding studies could be summarized into three categories: material deprivation (less income, goods, and access to services), isolation (physically and socially), and social inactivity (in terms of groups, politics, and economic activities).

Covariates

We used age, sex, educational attainment, marital status, and history of disease and impairment as covariates. These sociodemographic and health statuses are known to be strong predictors of subsequent health and they were used in many studies on social determinants of health (Moon, Kondo, Glymour, & Subramanian, 2011; Muller, 2002). Marital status was categorized as married, widowed/separated, unmarried, and other. Information on the history of disease and impairment was gathered using two questions about receiving medical treatment and the reasons for receiving medical treatment with 20 response options about diseases and/or impairments. From these questions, we created three categories, namely, no disease or impairment, only disease, and disease and/or impairment. We also considered the area of residence, adjusting for dummy variables of six municipalities (Handa, Tokoname, Agui, Taketoyo, Mihama, and Minami-chita) because a previous study using AGES data reported significant associations between regional characteristics, such as social capital and income inequality, and individual self-rated health (Ichida et al., 2009).

Statistical analysis

First, we calculated incidence rates (IRs) of mortality using baseline characteristics of respondents, and evaluated statistical differences using chi-square tests. Second, we used Cox's proportional hazard models to assess the effects of social exclusion on mortality, adjusting for potential multiple confounding factors. We graphically confirmed the proportionality of mortality hazards between the categories of social exclusion and sociodemographic variables, using Kaplane Meier survival curves. Finally, we calculated population attributable risk percentages (PAR%) in an older Japanese population. This estimation assumed that the adjusted relative risks truly reflected causal impact and that the AGES cohort represents the entire older Japanese population. Data on annual mortality of the population aged 65 or older was obtained from

Table 2
Baseline characteristics of respondents and incident rates of onset of mortality.[a]

Variable		n	IR	p	% Total	% Men	% Women
Sex	Men	6508	0.028	<.000	48.9	e	e
	Women	6802	0.013		51.1	e	e
Age group	<70	4700	0.010	<.000	35.3	37.7	33.0
	70e 74	3934	0.015		29.6	30.7	28.4
	75e 79	2819	0.026		21.2	19.9	22.4
	80e 84	1272	0.038		9.6	8.2	10.8
	85+	585	0.088		4.4	3.4	5.3
Educational attainment (years)	S 13	1228	0.018	.000	9.2	13.6	5.0
	10e 12	3714	0.017		27.9	27.0	28.8
	6e 9	7017	0.021		52.7	51.0	54.3
	<6	561	0.037		4.2	2.4	6.0
	Unknown	790	0.023		5.9	6.0	5.9
Marital status[b]	Married	8973	0.018	.001	72.0	89.1	55.5
	Divorced/separated	3212	0.024		25.8	9.8	41.1
	Never married	222	0.021		1.8	0.6	2.9
	Other	62	0.021		0.5	0.5	0.5
Disease and/or impairment	No	2211	0.013	<.000	16.6	17.7	15.5
	Only disease	7156	0.019		53.8	53.7	53.8
	Disease and/or impairment	3280	0.029		24.6	24.7	24.6
	Unknown	663	0.015		5.0	3.8	6.1
Municipality of residence	Handa	2540	0.021	.045	19.1	21.2	17.1
	Tokoname	2356	0.022		17.7	16.6	18.7
	Agui	1944	0.018		14.6	14.9	14.3
	Taketoyo	2464	0.019		18.5	19.2	17.9
	Mihama	1789	0.018		13.4	13.0	13.9
	Minami-chita	2217	0.023		16.7	15.2	18.1
Relative poverty[b]	1.13 Million yen+	8925	0.019	.012	85.0	88.3	81.1
	<1.13 Million yen (A)	1576	0.024		15.0	11.7	18.9
Social isolation[b]	Not isolated	10,870	0.005	<.000	84.5	79.3	89.5
	Isolated (B)	1994	0.022		15.5	20.7	10.5
Social inactivity[b]	Having hobby	9341	0.017	<.000	77.7	80.1	75.3
	No hobby: evitable reason	1778	0.030		14.8	13.0	16.6
	No hobby: inevitable reasons (C)	902	0.025		7.5	6.9	8.1
Social exclusion[b]	None	6586	0.017	<.000	67.8	66.7	69.0
	Only (A)	992	0.020		10.2	7.1	13.9
	(B) and/or (C)	1736	0.025		17.9	22.2	12.6
	(A) and (B) and/or (C)	405	0.026		4.1	3.9	4.5

IR: incidence rate.
[a] Cumulative incidence = 1044 in 51,208 person-years. IR = 0.020.
[b] Unknown cases were eliminated.

governmental reports, i.e., 960,917 deaths in 2008 (MHLW, 2008). All p-values were two tailed. We used the computer software SPSS version 12.0J (SPSS Japan Inc., Japan).

Results

We observed 51,208 person-years. During the four years of follow up, 1044 participants (7.8%) died, of which 689 (66.0%) were men. IRs were 0.028 for men and 0.013 for women. At baseline, 11.8% of participants were relatively poor, 15.0% were social isolated, and 7.5% were socially inactive due to inevitable reasons. IRs of mortality significantly varied across age, educational attainment, health status, and all dimensions of social exclusion (Table 2).

All dimensions of social exclusion were associated with higher hazard ratio (HR) for mortality, even after adjusting for potential confounding factors (Table 3). The adjusted HR was 1.27 (95% CI: 1.06e 1.52), between those who were socially isolated and/or socially inactive, and those who were not socially excluded. The adjusted HR was 1.29 (95% CI: 0.93e 1.80) between those living in relative poverty and those who were social isolation/inactivity. On the other hand, the adjusted HR of those who were relatively poor but not socially isolated/inactive was relatively small: 1.09 (95% CI: 0.86e 1.40).

There was a gender difference in the magnitude of the association between social exclusion and mortality (Table 4). In men, the adjusted HR of living in relative poverty (HR = 1.24, 95% CI: 0.95e 1.56) and social inactivity (HR = 1.33, 95% CI: 1.00e 1.78) were statistically significant, whereas the adjusted HR of being socially isolated was larger for women (HR = 1.72, 95% CI: 1.31e 2.25). Relative impoverishment did not predict mortality of women, if they were not social isolated and/or inactive. Adjusted HR was 1.10 for women, whereas it was 1.24 for men. The impact of being relatively poor and socially isolated and or inactive was much stronger among women (HR = 1.73) than men (1.11).

PAR% for each domain of social exclusion ranged from 2.6% to 2.8% (Table 5). PAR was 0.9% for those who were only relatively poor, 4.6% for socially isolated and/or socially inactive, and 1.2% for relatively poor and socially isolated and/or inactive.

Discussion

Using prospective data from a large sample of older Japanese adults, our epidemiologic study demonstrated that social exclusion predicted premature mortality. Given the annual mortality of the older Japanese population, our estimates of PAR% indicated that about 9000e 44,000 premature deaths (1e 5% of all deaths) could be avoided annually, if there was less social exclusion. We also identified the differential gender patterns for the impact of social exclusion on mortality. For men, relative poverty had stronger impact on their health than women, while the impact of social isolation was much stronger for women than men. The overall impact of social exclusion on mortality was stronger among Japanese women than men.

Our study suggested gender differences in the impact of social exclusion on mortality. It is specifically important that relative poverty might not be a risk for mortality among females but their mortality risk largely increases once they are isolated and/or inactive in their community; while relative poverty seems to be an independent risk factor for mortality among older men. These findings suggest that the primary pathways explaining the link of social exclusion to health for women might be limited interactions with close family or friends, whereas for men it might be

Table 3
Proportional hazard models for mortality.

Variable		Model 1		Model 2		Model 3		Model 4	
		HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI
Social exclusion	Relatively poor (A)	1.18	0.98e 1.42						
	Socially isolated (B)			1.19	1.02e 1.39				
	No hobby due to inevitable reasons (C)					1.34	1.07e 1.69		
	Only (A)[a]							1.09	0.86e 1.40
	(B) and/or (C)[a]							1.27	1.06e 1.52
	(A) and (B) and/or (C)[a]							1.29	0.93e 1.80
Sex	Men	2.61	2.20e 3.09	2.56	2.20e 2.97	2.68	2.29e 3.13	2.39	2.01e 2.87
Age group	< 70 (Ref)								
	70e 74	1.33	1.08e 1.64	1.31	1.07e 1.59	1.32	1.07e 1.63	1.26	1.01e 1.58
	75e 79	2.36	1.92e 2.90	2.37	1.96e 2.87	2.50	2.05e 3.06	2.35	1.90e 2.92
	80e 84	3.18	2.49e 4.06	3.48	2.81e 4.31	3.59	2.86e 4.51	3.37	2.61e 4.35
	85+	7.96	6.19e 10.23	8.12	6.48e 10.17	8.59	6.78e 10.90	8.27	6.35e 10.76
Educational attainment (years)	S 13 (Ref)								
	10e 12	1.09	0.84e 1.41	1.10	0.93e 1.48	1.10	0.85e 1.43	1.09	0.84e 1.43
	6e 9	1.20	0.94e 1.54	1.18	0.86e 1.41	1.14	0.59e 1.45	1.16	0.90e 1.50
	< 6	1.55	1.08e 2.23	1.48	1.06e 2.04	1.32	0.93e 1.87	1.42	0.97e 2.10
	Unknown	0.80	0.43e 1.47	0.95	0.60e 1.50	0.92	0.55e 1.53	0.72	0.35e 1.51
Marital status	Married (ref)								
	Divorced/separated	1.31	1.09e 1.57	1.27	1.08e 1.50	1.30	1.09e 1.55	1.31	1.07e 1.59
	Never married	1.24	0.66e 2.33	1.68	1.04e 2.70	1.69	1.04e 2.77	1.27	0.67e 2.39
	Other	1.40	0.82e 2.40	1.53	1.05e 2.24	1.38	0.89e 2.15	1.31	0.67e 2.53
Disease and/or impairment	No (ref.)								
	Only disease	1.58	1.24e 2.01	1.41	1.14e 1.73	1.49	1.19e 1.85	1.57	1.22e 2.02
	Disease and/or impairment	2.02	1.57e 2.59	1.70	1.37e 2.12	1.74	1.38e 2.19	1.98	1.52e 2.57
	Unknown	1.08	0.68e 1.70	1.00	0.69e 1.46	0.97	0.64e 1.46	0.98	0.58e 1.66
Municipality of residence	Handa (ref.)								
	Tokoname	0.97	0.78e 1.20	0.91	0.75e 1.11	0.90	0.74e 1.11	0.93	0.74e 1.17
	Agui	0.88	0.69e 1.12	0.85	0.68e 1.06	0.85	0.68e 1.07	0.87	0.69e 1.14
	Taketoyo	0.86	0.69e 1.08	0.94	0.77e 1.15	0.96	0.78e 1.19	0.88	0.69e 1.11
	Mihama	0.87	0.68e 1.11	0.87	0.70e 1.09	0.84	0.66e 1.06	0.89	0.69e 1.15
	Minami-chita	0.93	0.74e 1.18	1.06	0.87e 1.30	0.97	0.78e 1.20	0.93	0.72e 1.19

HR: hazard ratio, CI, confidence intervals.
Number of sample were as follows; Model 1 = 10,501, Model 2 = 12,864, Model 3 = 12,021 and Model 4 = 9719.
[a] Referent category is "neither (A), (B), nor (C)".

Table 4
Differences of hazard ratio for mortality between men and women.

	n	Men		Women	
		HR	95% CI	HR	95% CI
Relatively poor (A)	1576	1.24	0.95e 1.56	1.10	0.81e 1.49
Socially isolated (B)	1994	1.02	0.85e 1.24	1.72	1.31e 2.25
No hobby due to inevitable reasons (C)	902	1.33	1.00e 1.78	1.35	0.92e 2.00
Only (A)[a]	992	1.18	0.86e 1.62	0.99	0.67e 1.47
(B) and/or (C)[a]	1736	1.21	0.98e 1.48	1.46	1.03e 2.09
(A) and (B) and/or (C)[a]	405	1.11	0.72e 1.71	1.73	1.03e 2.90

HR: hazard ratio; CI, confidence intervals.
All estimates were controlled for age, educational attainment, marital status, disease and/or impairment, and municipality of residence.
[a] Referent category is neither (A), (B), nor(C).

psychosocial stresses due to poverty relative to others in their society, as well as material deprivation. Studies in Japan and Sweden have suggested that the health impacts of psychosocial stress due to relative deprivation might be stronger for men than women (Kondo, Kawachi, et al., 2009; Yngwe, Fritzell, Lundberga, Diderichsen, & Burströmb, 2003). In addition, interpersonal relationships among older women might have strong protective or buffering effects for psychosocial stress. In many cases older women are integrated into an extensive community network; thus the overlap of relative poverty and social isolation might strongly enhance social stress for older women, as such cases are rare among older women in the community. Nonetheless, study findings on the gender differences in the association between social relationships and health has been mixed. Berkman and Syme (1979), Orth-Gomér and Johnson (1987), and Forster and Stoller (1992) found that the differences in mortality rates between people with high and low social contact scores were greater for women than for men, whereas other studies reported stronger network effects for men (Kaplan et al., 1988; Schoenbach, Kaplan, & Fredman, 1986; Sugisawa, 1994).

The association between low income and poor health has been established in Japan and many other countries (Back & Lee, 2010; Ichida et al., 2009; Kondo, 2010; Oshio & Kobayashi, 2010). A recent meta-analysis of 148 studies revealed that the impact of social relationships and social support on health was similar to tobacco smoking, and individuals with adequate social relationships have a 50% greater likelihood of survival compared to those with poor or insufficient social relationships (Holt-Lunstad, Smith, & Layton, 2010). La Veist, Sellers, Brown, and Nickerson (1997) reported that extremely socially isolated older African American women, who were living alone and had no contact with family or friends in the 2 weeks prior to the survey, were 3 times more likely to die prematurely than non-isolated women. Similar evidence was provided in a 12-year follow-up study of 637 older Japanese people, Having fewer close friends (HR = 2.22) and group memberships (HR = 1.89) were associated with increased mortality in older men, but not in women (Sato et al., 2008). Moreover, there is abundant evidence for the link of social inactivity to poor health outcomes such as dementia (Takeda, Kondo, Hirai, & Murata, 2007; Wang, Karp, Winblad, & Fratiglinoi, 2002) and functional disability (Haga, Shibata, & Ueno, 1991; Kondo, Kazama, Suzuki, & Yamagata, 2008; Kondo, Minai, Imai, & Yamagata, 2007) in Japan.

Table 5
Estimated population attributable risks in Japan.

	n	% Exposed[a]	Mortality		
			HR	PAR[b]	
				%	n
Relatively poor (A)	1576	15.0	1.18	2.6	24,949
Socially isolated (B)	1994	15.5	1.19	2.8	27,068
Socially inactive due to inevitable reasons (C)	902	7.5	1.34	2.5	24,168
Only (A)	992	10.2	1.09	0.9	9126
(B) and/or (C)	1736	17.9	1.27	4.6	43,987
(A) and (B) and/or (C)	405	4.2	1.29	1.2	11,603

[a] These % exposed were in our study participants.
[b] PAR (%) = Pe(HR − 1)/Pe(HR − 1) + 1; Pe, the proportion of exposure in the target population; HR, hazard ratio.

Our study added new evidence on the gender-specific impact of multiple aspects of social exclusion on the mortality of older adults. One important finding is that the overall impact of social exclusion on mortality was stronger than a single dimension of social exclusion in women. Social exclusion could create multiple disadvantages for health including the lack of instrumental, emotional, and informational social support and access to health services. Santana (2002) conducted a cross-sectional study in Portugal and found that socially disadvantaged older adultsd in terms of socially excluded groups: living in poverty, long-term unemployment, and homelessnessd all showed lower utilization rates of health services.

Study limitations

Our study has several limitations. First, our evaluation of social exclusion did not cover the full range of dimensions that have been conceptualized in preceding studies. For example, information on material deprivation such as housing conditions was lacking. However, it is likely that the impact of material deprivation on health can be largely reflected by the effect of relative financial poverty, which was formally evaluated in our analyses. Second, we could not model temporal changes in social exclusion, the dynamic link between social exclusion and health deserves further study (Berghman, 1995). Third, caution is needed when interpreting our estimation of attributable risks as it requires a somewhat strong assumption that the data we used for this analysis are generalizable to the entire Japanese population, although our study participants were from six rural and suburban municipalities. Fourth, the response rate was not high (50.4%). The impact of this moderate response rate on the internal validity of this perspective study may be limited, however, and our findings might actually be underestimated. The responses that we obtained could be skewed toward social inclusion and the participants, themselves, may be healthier individuals, because people who were socially excluded might less be likely to participate in a social survey. In addition, we did not account for potential confounding factors that were not measured in this study. For example, contextual determinants of social exclusion (e.g., built environment for promoting social interactions and region-specific social security measures for older adults) are important factors potentially affecting both social exclusion and health, which deserve further study.

Conclusion

Worldwide, the population has been aging at an unprecedented pace (United Nations, 2001). In this study in Japan, where the society is the oldest in the world, we have revealed that there is a considerable proportion of the older population that is socially excluded and the attributable risk is large. Thus, policy intervention to promote social inclusion of the population, along with effective social security to support economically disadvantaged older adults should be required in Japan and many other countries. Numerous studies have suggested that older men tend to have narrower interpersonal relationships than women and they are more likely to experience social isolation (Saito et al., 2010; Tunstall, 1966). In fact, we found that the prevalence of social isolation was two times higher among men than women (20.7% vs. 10.5%). On the other hand, although most women are likely to have richer social networks than men, their health risks could be larger, if they lose their networks. Therefore, community activities aiming to promote social inclusion should be designed with a good understanding of these gender-specific factors of social exclusion. Future important research tasks might be to clarify the mechanisms of these gender differences and to develop effective gender-specific approaches for the issue of social exclusion of older adults.

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Income inequality, social capital and self-rated health and dental status in older Japanese

Jun Aida[a,b,*], Katsunori Kondo[c], Naoki Kondo[d], Richard G. Watt[a], Aubrey Sheiham[a], Georgios Tsakos[a]

[a] Department of Epidemiology and Public Health, University College London, 1-19 Torrington Place, London WC1E 6BT, UK
[b] Department of International and Community Oral Health, Tohoku University Graduate School of Dentistry, Sendai, Japan
[c] Center for Well-being and Society, Nihon Fukushi University, Nagoya, Japan
[d] Department of Health Sciences, Interdisciplinary Graduate School of Medicine and Engineering, University of the Yamanashi, Chuo-shi, Japan

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abstract

The erosion of social capital in more unequal societies is one mechanism for the association between income inequality and health. However, there are relatively few multi-level studies on the relation between income inequality, social capital and health outcomes. Existing studies have not used different types of health outcomes, such as dental status, a life-course measure of dental disease reflecting physical function in older adults, and self-rated health, which reflects current health status. The objective of this study was to assess whether individual and community social capital attenuated the associations between income inequality and two disparate health outcomes, self-rated health and dental status in Japan.

Self-administered questionnaires were mailed to subjects in an ongoing Japanese prospective cohort study, the Aichi Gerontological Evaluation Study Project in 2003. Responses in Aichi, Japan, obtained from 5715 subjects and 3451 were included in the final analysis. The Gini coefficient was used as a measure of income inequality. Trust and volunteering were used as cognitive and structural individual-level social capital measures. Rates of subjects reporting mistrust and non-volunteering in each local district were used as cognitive and structural community-level social capital variables respectively. The covariates were sex, age, marital status, education, individual- and community-level equivalent income and smoking status. Dichotomized responses of self-rated health and number of remaining teeth were used as outcomes in multi-level logistic regression models.

Income inequality was significantly associated with poor dental status and marginally significantly associated with poor self-rated health. Community-level structural social capital attenuated the covariate-adjusted odds ratio of income inequality for self-rated health by 16% whereas the association between income inequality and dental status was not substantially changed by any social capital variables. Social capital partially accounted for the association between income inequality and self-rated health but did not affect the strong association of income inequality and dental status.

Introduction

A recent meta-analysis showed that income inequality affects mortality and self-rated health (Kondo, Sembajwe, et al., 2009). There are several possible pathways linking income inequality and health (Kawachi, Fujisawa, & Takao, 2007). First, societies with high levels of income inequality have higher proportions of people living in poverty, and poverty is harmful for health (Shaw, Dorling, & Smith, 2006). Second, more unequal societies have higher levels of psychological stress caused by social comparisons, which in turn may have detrimental effects on health. Indeed, social-evaluative threats, one of the main causes of stress (Dickerson & Kemeny, 2004), are more common in more unequal societies (Wilkinson & Pickett, 2009). Third, income inequality erodes social capital and social capital is associated to health (Kawachi, Kennedy, Lochner, & Prothrow-Stith, 1997).

Although there is a growing body of evidence that social capital is associated with various health outcomes (Islam, Merlo, Kawachi, Lindstrom, & Gerdtham, 2006; Kim, Subramanian, & Kawachi, 2008), only a few non-ecological studies have examined the

* Corresponding author. Department of Epidemiology and Public Health, University College London, 1-19 Torrington Place, London WC1E 6BT, UK. Tel.: +44 (0) 20 7679 5665; fax: +44 (0) 20 7813 0280.
E-mail addresses: j-aida@umin.ac.jp, aidajun@m.tohoku.ac.jp (J. Aida).

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contribution of social capital to the association between income inequality and health, whilst considering contextual effects and undertaking multi-level analysis (Celeste, Nadanovsky, Ponce de Leon, & Fritzell, 2009; Ichida et al., 2009; Kim & Kawachi, 2007; Subramanian, Kawachi, & Kennedy, 2001). Social capital is defined as those features of social organizations, such as civic participation, norms of reciprocity, and trust in others, which facilitate cooperation for mutual benefit (Putnam, 1993). Social capital is embedded in communities and individuals (Kawachi et al., 1997). Multilevel modeling has been used to evaluate contextual community-level effects of social capital, controlling for compositional (individual-level) effects of social capital (Kawachi, Subramanian, & Kim, 2008). Of the previous studies assessing the relative effects of social capital and income inequality on health, most have used only community-level social capital (Celeste et al., 2009; Kim & Kawachi, 2007; Subramanian et al., 2001). In addition, a study by Ichida et al. (2009) evaluated community-level contextual effects of social capital adjusting for individual-level compositional effects, though it used only cognitive social capital.

Most of the cross-sectional studies on social capital and health have used self-rated health as an outcome variable. Few studies have used physical indicators of health as an outcome (Islam et al., 2006; Kim et al., 2008). In terms of function of older people, the number of remaining teeth is an important indicator of physical health. Dental health among older people is associated with impacts on daily living, particularly eating difficulties and nutritional deficiencies (Locker, 1992; Nowjack-Raymer & Sheiham, 2003, 2007; Sahyoun, Lin, & Krall, 2003; Sheiham et al., 2001; Tsakos, Herrick, Sheiham, & Watt, 2010; Walls & Steele, 2004) while periodontal disease and tooth loss are associated with mortality (Abnet et al., 2005; Appollonio, Carabellese, Frattola, & Trabucchi, 1997; Shimazaki et al., 2001) and chronic conditions such as hypertension (Franek et al., 2009; Tsakos, Sabbah, et al., 2010; Volzke et al., 2006), cardiovascular disease (Buhlin, Gustafsson, Pockley, Frostegard, & Klinge, 2003; D'Aiuto et al., 2006; Holmlund, Holm, & Lind, 2006; Meurman, Sanz, & Janket, 2004) and metabolic syndrome (D'Aiuto et al., 2008; Shimazaki et al., 2007).

The number of remaining natural teeth and self-rated health can be considered as complementary measures of health in older people as they reflect past and current exposures to health risks. Self-rated health, a key measure of health in older people has been used in epidemiological studies because it predicts future health outcomes (Moller, Kristensen, & Hollnagel, 1996) including mortality (Idler & Benyamini, 1997). Current self-rated health reflects current health status (Solomon, Kirwin, Ness, O'Leary, & Fried, 2010). On the other hand, the number of remaining natural teeth is a historical measure of health and reflects the accumulation of exposures to social determinants of dental health throughout the life-course (Poulton et al., 2002). No previous studies on the association of health with social capital or income inequality have simultaneously used self-rated health and dental status.

This study was therefore planned with the objective of examining whether individual- and community-level social capital attenuated the associations between income inequality and two disparate health outcomes, self-rated health and dental status (number of remaining natural teeth).

Methods

Study population

The present analysis is based on data from the Aichi Gerontological Evaluation Study Project (the AGES Project), an ongoing Japanese prospective cohort study (Aida et al., 2009; Kondo, 2010; Kondo, Kawachi et al., 2009). The AGES Project investigates factors associated with health related to functional decline or cognitive impairment among individuals aged 65 years or over. The AGES Project sample was restricted to people who did not already have physical or cognitive disability, defined as receiving a public long-term care insurance benefit. In 2003, a baseline mailed questionnaire survey was conducted on a random sample of community-dwelling individuals residing in 15 municipalities in 3 prefectures in Japan. In 2010, 10 municipalities located in Aichi prefecture approved the use of detailed area identification, so the participants from these areas could be assigned to a local district, according to their place of residence. There were 79 local districts in the 10 municipalities and all community-level variables were calculated on the basis of these districts (Hanibuchi et al., 2009). We used three sections of the questionnaire: dementia, oral health, and abuse of older people. The questionnaires containing questions about oral health were distributed to 11,455 older people in the 10 municipalities and their responses formed the basis for this research. Responses were obtained from 5715 subjects (49.5%). Because subjects were older people and self-complete questionnaires were used, there were several questionnaires with missing data, especially in relation to the question on income. After excluding respondents with missing data, data on 3451 were included in the analysis. The mean number of analyzed respondents per district in the 79 local districts was 44.4 (SD = 42.9, minimum = 7, maximum = 220, 25th percentile = 15, 50th percentile = 30, 75th percentile = 62).

The Ethics Committee on Research of Human Subjects at Nihon Fukushi University approved the AGES Project protocol.

Outcome variables

Self-rated health and number of remaining natural teeth were used as outcomes. Self-rated health was measured through the question "What is your current health status: excellent, good, fair, or poor?" For analysis purposes, this variable was dichotomized in the manner similar to that used by Ichida et al. (2009), Kim and Kawachi (2007) and Subramanian et al. (2001) as follows: (i) good ("excellent/good") and (ii) poor ("fair/poor"). To obtain data on dental status, respondents were asked to classify their dental status as having 20 or more teeth, having 19 or less teeth with dentures, having 19 or less teeth without any dentures, having very few teeth with dentures, or having very few teeth without any dentures. Retention of a minimum of 20 functional natural teeth at ages of 65 years and over was an oral health goal specified by the WHO and Federation Dentaire Internationale "Global Goals for Oral Health in the year 2000" (Federation Dentaire Internationale, 1982). The goal for an acceptable level of oral health set by the Japan Dental Association was retention of a minimum of 20 functional teeth at the age of 80. Previous research indicated that older people with 20 or more teeth had better nutritional intake than people with 19 or less teeth (Yoshihara, Watanabe, Nishimuta, Hanada, & Miyazaki, 2005). Therefore, dental status was used as a dichotomous variable: (i) having 20 or more teeth and (ii) having 19 or less teeth.

Main predictors

The Gini coefficient for the 79 local districts was used as an indicator of income inequality (De Maio, 2007). The Gini coefficient was used as a continuous variable ranging from 0 - completely equal distribution of equivalent income, to 1 - completely unequal distribution of equivalent income.

There are two distinct components of social capital: cognitive and structural (Islam et al., 2006). Cognitive social capital refers to what people feel and structural social capital to what people do (Harpham, 2008). We used both trust (cognitive social capital) and volunteer participation (structural social capital) as measures of social capital.

Trust was measured by the following question; "Generally speaking, would you say that most people can be trusted?" (response alternatives: "yes", "depends" and "no"). The responses "yes" and "depends" were grouped together for analysis. Respondents were also asked whether they belonged to a volunteer group (responses: "yes" or "no").

A community-level social capital variable was created by aggregating individual-level data (Kawachi et al., 2008). Rates of subjects reporting mistrust and non-volunteering in each 79 local district were used as cognitive and structural community-level social capital variables.

Covariates

Several previous studies that have assessed the association between income inequality and self-rated health used only socio-demographic covariates (Ichida et al., 2009; Kim & Kawachi, 2007; Subramanian, Delgado, Jadue, Vega, & Kawachi, 2003). Some studies also adjusted for lifestyle variables, such as smoking (Lopez, 2004; Xi, McDowell, Nair, & Spasoff, 2005, pp. 31e 45) and exercise (Xi et al., 2005). Smoking is an important lifestyle variable because it is a common risk factor for poor dental status and poor self-rated health. Sex, age group (65e 69 years, 70e 74, 75e 79, 80e 84 and 85 years or older), marital status (married, separated/ divorced, never married), educational attainment (years, <6, 6e 9, 10e 12 or ≥13), smoking status (never, ever, or current), individual- and community-level equivalent income were used as covariates in this study. Calculation of equivalent income took into account household income and number of household members. The income question had 14 categories, and the midpoints were set as household income in each category. We adjusted household income for household size, dividing the income by the square root of the number of people in that household. As the association between health and income has been suggested to be non-linear (Kawachi, 2000; Rodgers, 1979), the individual-level equivalent income was used as a categorical variable (ten thousand Yen, <150, 150e 199, 200e 249, 250e 299, 300e 349, 350e 399, 400e 449, 450e 499, ≥500). The mean individual-level equivalent income in each of the 79 local districts determined the community-level income variable.

Analysis

In the data set, individuals (first-level) were nested in local districts (second-level). The analysis framework anticipated that the individual health outcomes would be partly dependent on the districts where individuals live. We used multi-level models to estimate the variation of the outcomes between districts (random effects) and the effect of community-level variables on the outcomes with adjustment for individual compositional characteristics (fixed-effects). Since the outcomes were dichotomous, multi-level logistic regression models with random intercepts and fixed slopes were applied using the MLwiN 2.20 software package (Centre for Multilevel Modelling, University of Bristol, UK). Self-rated health and number of remaining teeth were used as the outcome variables. Odds ratios were calculated for: a) having poor self-rated health and b) 19 or less teeth. Odds ratios were calculated for 0.1 point difference in the community-level mistrust and non-volunteering rates. We also calculated odds ratios associated with 0.1 point difference in Gini coefficient, while the odds ratios calculated for community-level equivalent income referred to 100 thousand-yen difference.

Univariate multi-level odds ratios were calculated to show crude associations of all variables with each outcome. To test our hypothesis, we used the following models. To distinguish the individual-level compositional effect and community-level contextual effect of social capital on outcomes, individual- and community-level social capital variables were separately added into the models. Model 1 was used to assess the association between outcomes and income inequality (Gini coefficient), adjusted for sex, age, marital status, educational attainment, smoking status, individual- and community-level income. In Model 2, to check the attenuation of the association between Gini and outcome by community-level structural social capital, we added community-level volunteering. In Model 3, to check on the attenuation of the association between Gini and outcome by both individual- and community-level structural social capital, individual-level volunteering was added to Model 2. Model 4 was similar to Model 1 but additionally adjusted for community-level trust to assess whether community-level cognitive social capital attenuates the association between outcomes and income inequality. In Model 5, to check the attenuation of the association between Gini and outcome by both individual- and community-level cognitive social capital, individual-level trust was added to the Model 4. In Models 3 and 5, individual-level volunteering and trust were centered around the local district mean to make them orthogonal, thus addressing the issue of collinearity between individual- and community-level social capital indicators (Kawachi et al., 2008).

Parameters were estimated using Markov Chain Monte Carlo methods with chain length 50,000 burn in 5000. We calculated median odds ratios (MORs) to evaluate the community-level variances in different outcomes (Merlo et al., 2006). If the median odds ratio is 1, there is no variation between communities. If there is a substantial community-level variation, the median odds ratio will be large. The measure is directly comparable with fixed-effects odds ratios. The Deviance Information Criterion was used to compare the goodness-of-fit of each model.

Results

Table 1 shows the demographic distribution and univariate association between self-rated health, number of remaining teeth and covariates. Communities with higher income inequality had increased risks of poor self-rated health (OR = 1.39) and poor dental status (OR = 1.86). Community level mistrust was not significantly associated with self-rated health and dental status. Communities with higher levels of non-volunteering had increased risks of poor self-rated health (OR = 1.57) and poor dental status (OR = 1.42). Individual subjects reporting mistrust and who were non-volunteers had relatively poor self-rated health (OR = 1.94 and OR = 1.95, respectively) and poor dental status (OR = 1.52 and OR = 1.58, respectively).

There were variations in self-rated health and dental status between communities in the intercept-only models (community-level variance (SE); 0.018 (0.017) for self-rated health and 0.037 (0.026) for dental status), which showed pure community-level variations in the outcomes. Variation of dental status between communities was larger than that for self-rated health (MOR = 1.20, 95% CI = 1.05e 1.35 and MOR = 1.14, 95% CI = 1.03e 1.27, respectively). These figures indicated that if a person moved to another area with a higher probability of poor dental status, their median risk of poor dental status would increase by 1.20 times; similarly, if a person moved to an area with a higher probability of poor self-rated health, their median risk of poor self-rated health would increase by 1.14 times.

Variations in dental status between communities were substantially explained by the Gini coefficient. When Gini

Table 1
Univariate associations between self-rated health, dental status and explanatory variables: The Aichi Gerontological Evaluation Study, Aichi, Japan, 2003 (N = 3451).

		N	Self-rated health			Dental health		
			Good (%)	Poor (%)	Univariatee multilevel odds ratio	20 or more (%)	19 or less (%)	Univariatee multilevel odds ratio
Categorical variables								
Sex	Male	1861	70.4	29.6	Reference	34.0	66.0	Reference
	Female	1590	73.5	26.5	0.86 (0.74 e 0.99)	33.1	66.9	1.03 (0.90 e 1.19)
Age	65e 69	1370	78.2	21.8	Reference	45.4	54.6	Reference
	70e 74	1042	71.7	28.3	1.42 (1.17 e 1.71)	33.1	66.9	1.69 (1.43 e 2.00)
	75e 79	660	61.7	38.3	2.23 (1.83 e 2.74)	21.5	78.5	3.06 (2.47 e 3.79)
	80e 84	252	64.7	35.3	1.97 (1.47 e 2.63)	16.7	83.3	4.21 (3.00 e 6.03)
	≥85	127	70.9	29.1	1.46 (0.97 e 2.19)	6.3	93.7	13.14 (6.52 e 30.2)
Marital status	Married	2678	71.5	28.5	Reference	35.5	64.5	Reference
	Separated/ divorced	723	73.0	27.0	0.93 (0.77 e 1.12)	26.1	73.9	1.56 (1.30 e 1.88)
	Never married	50	68.0	32.0	1.17 (0.63 e 2.12)	38.0	62.0	0.89 (0.50 e 1.63)
Educational attainment (years)	<6	122	60.7	39.3	2.28 (1.47 e 3.55)	14.8	85.2	4.15 (2.46 e 7.29)
	6e 9	1744	68.6	31.4	1.60 (1.25 e 2.09)	30.3	69.7	1.61 (1.29 e 2.01)
	10e 12	1162	75.7	24.3	1.12 (0.86 e 1.47)	37.7	62.3	1.17 (0.92 e 1.48)
	≥13	423	77.5	22.5	Reference	41.4	58.6	Reference
Individual-level equivalent income (ten thousand Yen)	<150	774	68.1	31.9	1.88 (1.27 e 2.88)	26.2	73.8	1.50 (1.04 e 2.13)
	150e 199	605	69.1	30.9	1.79 (1.20 e 2.76)	32.6	67.4	1.11 (0.77 e 1.60)
	200e 249	776	71.9	28.1	1.57 (1.05 e 2.41)	36.7	63.3	0.92 (0.64 e 1.31)
	250e 299	226	76.5	23.5	1.21 (0.75 e 1.97)	33.2	66.8	1.08 (0.70 e 1.65)
	300e 349	360	71.4	28.6	1.60 (1.03 e 2.55)	37.2	62.8	0.91 (0.61 e 1.34)
	350e 399	283	75.3	24.7	1.32 (0.83 e 2.13)	35.0	65.0	1.00 (0.66 e 1.51)
	400e 449	163	73.0	27.0	1.48 (0.88 e 2.50)	38.7	61.3	0.85 (0.54 e 1.34)
	450e 499	101	82.2	17.8	0.85 (0.44 e 1.60)	45.5	54.5	0.63 (0.38 e 1.05)
	≥500	163	79.8	20.2	Reference	35.0	65.0	Reference
Smoking status	Non	1971	73.3	26.7	Reference	36.2	63.8	Reference
	Past	969	68.2	31.8	1.29 (1.09 e 1.52)	31.8	68.2	1.22 (1.04 e 1.44)
	Current	511	72.8	27.2	1.03 (0.83 e 1.28)	27.0	73.0	1.54 (1.24 e 1.93)
Individual trust	Trust	3193	72.9	27.1	Reference	34.2	65.8	Reference
	Mistrust	258	58.1	41.9	1.94 (1.48 e 2.52)	25.6	74.4	1.52 (1.14 e 2.03)
Individual volunteering	Yes	389	82.3	17.7	Reference	43.2	56.8	Reference
	No	3062	70.5	29.5	1.95 (1.50 e 2.57)	32.4	67.6	1.58 (1.29 e 1.95)
Continuous variables (mean (SD))								
Community-level equivalent income (ten thousand Yen)[a]			244.8 (21.1)	243.2 (21.7)	0.96 (0.93 e 1.00)	246.4 (20.6)	243.3 (21.5)	0.93 (0.90 e 0.96)
Gini coefficient[b]			0.300 (0.030)	0.304 (0.035)	1.39 (1.10 e 1.70)	0.297 (0.029)	0.303 (0.033)	1.86 (1.46 e 2.29)
Rate of mistrust[b]			0.095 (0.022)	0.096 (0.022)	1.20 (0.83 e 1.69)	0.095 (0.022)	0.096 (0.022)	1.25 (0.86 e 1.79)
Rate of none volunteering[b]			0.896 (0.028)	0.899 (0.028)	1.57 (1.27 e 2.00)	0.895 (0.027)	0.898 (0.028)	1.42 (1.13 e 1.82)

[a] Odds ratios for 100 unit difference in community-level equivalent income are shown.
[b] Odds ratios for 0.1 unit difference in Gini coefficient, rate of mistrust and rate of non-volunteering are shown.

coefficient was added into the intercept-only model the median odds ratio for number of remaining teeth was reduced by 50% (MOR = 1.10, 95% CI = 1.02e 1.22). On the other hand, the median odds ratio associated with self-rated health did not substantially change (MOR = 1.12, 95% CI = 1.03e 1.23).

Table 2 shows the multivariate association with self-rated health and explanatory variables. After adjusting for sex, age, marital status, educational attainment, individual- and community-level equivalent income and smoking status, the multi-level odds ratio of Gini coefficient for poor self-rated health attenuated by 35.9% (from 1.39 to 1.25) and became non-significant (Model 1). After community-level non-volunteering was added to the model (Model 2), the odds ratio of income inequality was attenuated by 16.0% (OR = 1.21). When individual-level volunteering was also controlled for, the odds ratio of income inequality remained unchanged (Model 3). Individual- and community-level mistrust did not attenuate the association between income inequality and self-rated health (Models 4 and 5).

Table 3 shows the multivariate association for dental status and predictors. After adjusting for all covariates, higher income inequality was still associated with poor dental status (OR = 1.54). Individual- and community-level non-volunteering and mistrust did not substantially reduce the odds ratio of Gini coefficient, Deviance Information Criterion and median odds ratio (Models 2e 5).

Discussion

This study showed that income inequality in communities was significantly associated with poor self-rated health (OR = 1.39) and poor dental status (OR = 1.86) of older Japanese. Income inequality was a major contributor to the variation in dental status between communities (50% reduction of MOR), but not to self-rated health. The association between income inequality and dental status remained significant when social capital variables were included in the analyses. On the other hand, the association between income inequality and self-rated health was attenuated when community-level structural social capital was included in the model.

Living in an area with 0.1 point higher Gini coefficient was associated with a 39% higher risk of having poor self-rated health and with 86% higher risk of having 19 or fewer teeth. For dental status, the association was still significant, even after adjusting for individual equivalent income, community mean equivalent income, sex, age, marital status, educational attainment and smoking status. An important point to consider is that these contextual effects affect not only poor people but also residents in communities with rich people. These results were consistent with previous studies. A meta-analysis showed that the overall odds ratio for poor self-rated health was 1.04 (95% CI = 1.02e 1.06) per 0.05 unit increase in Gini coefficient (Kondo, Sembajwe et al., 2009). In our results, the adjusted odds ratio for poor self-rated