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Neighborhood farm density, types of agriculture, and depressive symptoms among older farmers: a cross-sectional study

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Abstract

Background: Farmers may have an increased risk for poor mental health. In connection with this, factors specific to the neighborhood environment such as farm density and the type of agriculture, might be important for mental wellbeing. In this study we aimed to clarify the cross-level interaction on depressive symptoms between farm density at the neighborhood level by type of agriculture and the longest occupation of individuals (farmer or non-farmer).

Methods: Data came from the 2016 wave of the Japan Gerontological Evaluation Study (JAGES) that were linked to governmental agricultural data. Information was analyzed from 147,549 respondents aged 65 years or older, residing in 1024 neighborhoods in 39 municipalities. We calculated farm (crop or animal husbandry) density at the neighborhood level, dividing the number of agricultural management entities by the population. Three-level (individual, neighborhood, and municipality) Poisson regression analysis was used to calculate the prevalence rate ratios of depressive symptoms.

Results: The prevalence of depressive symptoms was higher among individuals whose longest occupation was farmer compared to non-farmer. The estimated probability of depressive symptoms by a cross-level interaction analysis showed that among farmers of both genders, those who were residing in neighborhoods where the farm density was low had a higher prevalence of depressive symptoms, regardless of the type of agriculture. The slope of the relationship between depressive symptoms and animal husbandry farm density varied by occupation, with a higher prevalence of depressive symptoms observed in male farmers compared to male non-farmers.

Conclusions: The high prevalence of depressive symptoms among farmers in neighborhoods with a low farm density may reflect a scarcity of formal and informal social support in such communities. The health effects of the neighborhood environment on farmers, such as farm density, which may vary by the type of agriculture, should be further researched.

Keywords: Farm density, Depression, Farmer, Neighborhood, Japan, Older adults, Animal husbandry, Crop, Agriculture, Health effect

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Background

Farmers are one of the groups that have been reported to have poor mental health worldwide, which suggests that structural factors in agriculture may play a role in their psychological wellbeing. In various countries, a variety of mental health outcomes including depression, anxiety, and psychological morbidity are all higher among farmers compared to non-farmers [1, 2]. Systematic reviews on suicide and occupation have also found that the suicide risk among farmers is higher than among individuals in other jobs [3, 4]. Although farming practices and the agricultural context vary among farms within and between countries, there is a common global context including increasing global competition, a decline in the number of farms, increasing farm size, and climate variability [3, 5–7]. The structural changes that are occurring in the agricultural sector are linked to a number of risk factors for poor mental health among farmers including an increasing economic burden, geographical and social isolation, as well as difficulty in obtaining help [1, 3, 8, 9].

In Japan, farming is characterized by both a declining and aging farming population; between 2000 and 2015 the number of people who worked mainly as farmers fell from 2.4 to 1.8 million, while in the same period the proportion of farmers aged 65 or above rose from 51 to 65% [10]. As the number of Japanese farms has decreased, it is possible that many farmers may have lost both friends and colleagues as other farmers have left farming communities. Losing this potential source of social support and social participation might have had a detrimental impact on farmers' mental health [9, 11]. However, to our knowledge, as yet, no study has investigated the association between agricultural structural change, as reflected for instance, in neighborhood farm density, and farmers' mental health, despite some evidence that Japanese farmers might be at an increased risk for worse mental health outcomes such as suicide [3, 12–14].

Different types of agriculture may be associated with differing community characteristics, which could also potentially relate to mental health problems. For example, studies have shown that work-related factors pertaining to animal husbandry, including a lack of offseason, animal diseases, economic pressure, as well as exposure to the death of livestock may all impact on a farmer's mental health [15–18]. Indeed, a recent ecological study that used Japanese municipal data found that suicide mortality was positively associated with animal husbandry output per unit of the municipality population whereas no association was observed for other forms of agricultural output [19]. However, that study did not take individual characteristics such as occupation into consideration and did not determine whether farmers had a higher suicide risk compared to other (non-farming) residents. This may have been an important omission as there is some evidence that community characteristics relating to the type of agriculture may affect not only farmers, but rather, *all* people in the community [20, 21].

With this in mind, this study had two objectives. First, using individual data from older adults in Japan, we aimed to determine if there was a cross-level interaction for depressive symptoms between farm density at the neighborhood level (animal husbandry or crop farming) and occupation (farmer or non-farmer). Second, we tested if the prevalence of depressive symptoms among residents was higher in areas where animal husbandry was common compared to areas where it was less common, and whether the association differed depending on the main occupation of the residents (farmer or non-farmer).

Methods

Data

Cross-sectional data were drawn from the 2016 wave of the Japan Gerontological Evaluation Study (JAGES). The JAGES project conducted an anonymous self-administered mail survey, in cooperation with municipalities across Japan. More specifically, a questionnaire was sent to residents aged 65 years or older in participating municipalities, who were not certified as needing public long-term care insurance. The 2016 wave included individuals living in 39 municipalities in Japan. Details of the participating municipalities are available on the JAGES website [22]. In 22 generally larger municipalities, participants were selected by multistage random sampling, while in 17 smaller municipalities all eligible individuals were selected. In total 279,661 questionnaires were mailed, of which 196,438 were returned (response rate = 70.2%). After excluding those who were certified as needing public long-term care insurance, data were available for 180,021 individuals. The data has a three-stage hierarchical structure; individuals, school districts (neighborhoods), and municipalities.

To evaluate what types of agriculture were present in each residential area we obtained government agricultural statistics for 2015 from the website of the Ministry of Agriculture, Forestry and Fisheries [23]. We used them to proportionally distribute agricultural data into each JAGES school district. We also obtained government geographical data relating to the covariates used in this study.

Measurements

Outcome: depressive symptoms

The Japanese short version of the Geriatric Depression Scale (GDS-15) was used to evaluate depressive

symptoms. This measure was developed to assess depressive symptoms in self-administered surveys and consists of 15 items with yes (scored 1) and no (0) answer options that give a total score that can range from 0 to 15 where higher scores indicate more depressive symptoms. We used a cut-off score of 6 and above to categorize depressive symptoms, as this score was used to indicate moderate depressive symptoms in an earlier validation study among older Japanese adults [24]. This cut-off score has also been reported to be highly associated with suicidal ideation [25].

Farm density by type(s) of agriculture

We calculated farm density at the school district level, i.e. the number of farms (agricultural management entities) per unit of the total population. First, we aggregated the data by the type of agriculture into "animal husbandry" and "crop" categories. The animal husbandry category included dairy farming, beef cattle farming, pig farming, poultry farming, sericulture, and other livestock activities. The crop category included the production of rice, wheat, potatoes, craft crops, vegetables grown outdoors, vegetables grown in greenhouses, fruits, flowers, and other agricultural crops. Next, we divided the number of agricultural management entities by unit total population. As the distribution of these values was right-skewed and contained 0, we added 0.5 to each value and logarithmically transformed them. Then, we standardized these values (subtracted the average from each figure and divided it by the standard deviation).

Longest occupation

Although many individuals can be categorized as engaging in 'farming' in Japan, including those who start small-scale farming following their retirement, in this study we defined a farmer as anyone who reported that the longest occupation they had engaged in across their life course was farming. This was done as the principal aim of this study was to determine the health effects of demographic and structural change in agriculture. We gathered information on each respondent's longest occupation by asking, "What is the type of occupation that you have participated in for the longest period in your life?" There were 9 predetermined response categories including (1) professional/technical, (2) managerial, (3) clerical, (4) sales/service, (5) skilled labor, (6) agriculture, forestry or fisheries, (7) self-employment other than agriculture, forestry, and fisheries, (8) other, (9) "I have never had a job." Respondents who answered 'agriculture, forestry or fisheries' were then classified as being "farmers", while all others were categorized as being "non-farmers."

Covariates

The development of agriculture is affected by geographical and climate factors. Using the literature that has examined the association between geographical and climatic factors and suicide as a guide [26–28], we included the following variables as potential confounding factors in the association between farm density by type of agriculture and depression: length of daylight hours (classified in tertiles - short, middle, long), amount of rainfall, and the mean slope angle of the habitable land, which were all calculated at the neighborhood level. Covariates relating to individual socioeconomic status included years of education (less than nine years or not i.e. equivalent to graduating junior high school), equivalized household income tertile (high, middle, low), marital status (having a spouse or not), and living alone or not [29–33]. We also adjusted by population density quintile (highest, high, middle, low, lowest) at the neighborhood level [34], by the administrative regions in Japan (Tokai, Hokkaido, Tohoku, Hokuriku, Kanto and Higashiyama, Kinki, Kyushu) using area dummies, and age (65–74, 75–84, > = 85).

Statistical analyses

In total 32,472 respondents were excluded from the analysis, including those without valid values for age (n = 262), gender (n = 30), residential address (n = 7), and depressive symptoms (n = 32,173). We calculated the prevalence ratio (PRs) of depressive symptoms using three-level (individual, neighborhood, and municipality) Poisson regression to take into account the hierarchical structure of the data containing variables measured at different areal levels. In order to avoid overestimating the PRs, Poisson regression with robust variance was used to model depressive symptoms, which can be regarded as a frequently occurring outcome [35]. We stratified all analyses by gender as mental health problems among farmers may be associated with socially constructed gender relations [8, 36]. We used the *mepoisson* command in STATA/MP 15.1 and incorporated random intercepts at the neighborhood level and the municipality level (StataCorp, LLC, College Station, Texas, USA). As we could not find a program to conduct multiple imputation using a three-level model, we created dummy variables for the missing covariate data and modeled them. We first analyzed a null (empty) model to evaluate the variance of the random parameters. To evaluate general contextual effects, we calculated Median Rate Ratios (MRRs) from the estimated variance of the random parameters. MRR refers to the median relative difference in the prevalence of depressive symptoms when comparing two randomly selected residents from groups with a higher and a lower prevalence of depressive symptoms [37]. We evaluated cross-

level interaction effects, i.e. "whether the nature of a lower-level relationship depends on a higher-level factor" [38]. To do so, we included higher-level explanatory variables (animal husbandry farm density and crop farm density), lower-level variables (longest occupation), an interaction term between each type of farm density (Model 1: animal husbandry farm density; Model 2: crop farm density) and longest occupation, and all the covariates in the model. From these models, we obtained the estimated probability of outcomes at the farm density quantile (lowest, low, high, highest). As there were many cases where the value of animal husbandry farm density was 0, we combined the first and second percentile of the animal husbandry farm density variable and then obtained estimates (low, middle, high). Furthermore, to evaluate whether the variation in depressive risk according to farm density differed by longest occupation, we evaluated the statistical significance of the cross-level interaction term. As the statistical power of cross-level interaction tests is severely limited, we considered a value of $p < 0.20$ as being indicative of a potentially significant interaction effect [38, 39].

Results

Data were analyzed from 70,988 men and 76,561 women, nested within 1024 neighborhoods in 39 municipalities. As shown in Table 1, about 4% of all respondents classified their longest occupation as farmer. More participants lived in the Tokai region than in any other region. Descriptive data of the study sample with the prevalence of depressive symptoms showed that 17.1% of all participants had depressive symptoms, and that the prevalence of depression was higher among farmers than non-farmers.

In the null model of the multilevel Poisson regression analysis the PR of depressive symptoms varied slightly between municipalities and between neighborhoods: the MRRs were 1.13 and 1.04 in men, 1.16 and 1.00 in women, respectively (Tables 2 and 3). After incorporating explanatory variables in the model, the MRRs decreased slightly both between municipalities and between neighborhoods (Model 1 and 2), indicating that a small part of the variance in depressive symptoms between areas was explained by these variables.

A cross-level interaction analysis showed that the probability of having depressive symptoms was higher among farmers than among non-farmers for both genders, and varied by the neighborhood farm density (Fig. 1). Among male farmers, the probability of having depressive symptoms was higher among those residing in neighborhoods where the farm density was low, compared to those in neighborhoods where the farm density was high. The estimated probability of having depressive symptoms among male farmers calculated from Model 1, which incorporated an interaction term between animal husbandry farm density and occupation, varied from 0.19 (95% confidence interval: 0.18 to 0.19) at the high animal husbandry farm density to 0.22 (0.21 to 0.23) at the low animal husbandry farm density. The estimated values calculated from Model 2, which incorporated an interaction term between crop farm density and longest occupation, varied from 0.19 (0.18 to 0.19) at the highest crop farm density to 0.25 (0.23 to 0.26) at the lowest farm density. Among female farmers, this relation was also observed for crop farm density: 0.19 (0.18 to 0.19) at the highest crop farm density to 0.27 (0.24 to 0.29) at the lowest, whereas the association was weak for animal husbandry farm density.

The p values for the interaction term showed that the slope of the relationship between depressive symptoms and animal husbandry farm density differed significantly between farmers and non-farmers among men (Fig. 1, the p value of the interaction term was 0.111). For crop farm density the variation in depressive risk did not differ significantly between farmers and non-farmers.

Discussion

In this study we analyzed data from 147,549 individuals aged 65 and above residing in 1024 neighborhoods in 39 municipalities, which were collected in the 2016 wave of the Japan Gerontological Evaluation Study. Cross-level interaction analyses showed that the probability of having depressive symptoms among farmers varied by farm density with a higher risk being observed among those who were residing in neighborhoods with a low farm density, regardless of the type of agriculture. Furthermore, the variation in depressive risk according to animal husbandry farm density differed between farmers and non-farmers with a significantly higher level of depressive symptoms observed in the former. Our findings suggest that the mental health of farmers might be potentially affected by neighborhood farm density, regardless of the specific type of agriculture.

This study sheds light on the potential effects of neighborhood farm density on the risk of depressive symptoms among farmers. In particular, the finding that for farmers, the risk of depression varied by neighborhood farm density may help explain a discrepancy in previous studies about farmers' depression. Specifically, a recent systematic review reported that although a majority of studies had found that there was a higher risk of depressive symptoms among farmers compared to in the general population, 30% of the studies nevertheless suggested that the risk was similar or even lower among farmers compared to non-farmers [1]. An earlier study conducted in a rural area in Japan showed for example, that farmers and non-farmers had a similar risk of experiencing depressive symptoms [40]. Our results may

Table 1 Descriptive statistics of the study participants with the prevalence of depressive symptoms

	Total	Men	Women
	Number of participants (prevalence of depressive symptoms (%))		
Individual-level variables			
Age			
65–74	86,815 (15.8)	42,005 (16.4)	44,810 (15.2)
75–84	51,792 (18.1)	24,757 (18.3)	27,035 (17.9)
> =85	8942 (23.6)	4226 (22.6)	4716 (24.5)
Education			
< =9 years	46,205 (21.9)	20,229 (23.4)	25,976 (20.8)
> 9 years	99,621 (14.7)	50,120 (14.9)	49,501 (14.5)
Missing	1723 (23.4)	639 (25.4)	1084 (22.2)
Equivalized household income tertile (10,000 yen/year)			
High (247.49 < =)	51,919 (10.0)	27,298 (10.0)	24,621 (10.0)
Middle (159.1–245.97)	33,392 (16.9)	17,322 (17.9)	16,070 (15.9)
Low (<=158.77)	33,475 (25.2)	15,152 (26.8)	18,323 (23.8)
Missing	28,763 (20.5)	11,216 (22.0)	17,547 (19.5)
Living alone			
No	118,902 (15.2)	60,990 (15.2)	57,912 (15.2)
Yes	21,432 (26.5)	7080 (35.4)	14,352 (22.1)
Missing	7215 (19.2)	2918 (19.6)	4297 (18.9)
Having spouse			
Yes	107,232 (14.6)	60,203 (14.9)	47,029 (14.2)
No	37,885 (23.3)	9665 (31.5)	28,220 (20.5)
Missing	2432 (29.0)	1120 (33.3)	1312 (25.4)
Longest occupation			
Not farmer	126,855 (16.7)	62,189 (17.1)	64,666 (16.3)
Farmer	5378 (19.1)	2771 (19.3)	2607 (18.9)
Missing	15,316 (19.3)	6028 (19.7)	9288 (19.1)
Area-level variables			
Population density quintile (person/km^2)			
Highest (11,759.42–37,915.64)	29,761 (17.2)	14,229 (18.0)	15,532 (16.4)
High (7431.47–11,753.88)	30,522 (16.4)	14,964 (16.9)	15,558 (15.8)
Middle (4868.92–7426.45)	29,209 (16.8)	14,155 (17.0)	15,054 (16.6)
Low (3476.89–4842.1)	29,537 (16.7)	14,094 (17.0)	15,443 (16.3)
Lowest (795.82–3456.73)	28,520 (18.4)	13,546 (18.2)	14,974 (18.5)
Area			
Tokai	62,932 (16.3)	30,440 (16.9)	32,492 (15.8)
Hokkaido	8486 (16.6)	4048 (16.2)	4438 (16.9)
Tohoku	7386 (20.6)	3479 (19.8)	3907 (21.4)
Hokuriku	6796 (18.7)	3314 (18.2)	3482 (19.2)
Kanto and higashiyama	35,974 (16.4)	17,651 (16.6)	18,323 (16.2)
Kinki	9426 (17.5)	4583 (19.4)	4843 (15.8)
Kyushu	16,549 (19.0)	7473 (19.4)	9076 (18.7)
Daylight hours tertile (hours/year)			
Short (1393.76–1886.62)	49,348 (16.9)	23,672 (17.4)	25,676 (16.3)

Table 1 Descriptive statistics of the study participants with the prevalence of depressive symptoms *(Continued)*

	Total	Men	Women
	Number of participants (prevalence of depressive symptoms (%))		
Middle (1886.68–2060.44)	49,797 (16.2)	24,481 (16.9)	25,316 (15.6)
Long (2060.46–2177.88)	48,404 (18.1)	22,835 (18.0)	25,569 (18.2)
Total	147,549 (17.1)	70,988 (17.4)	76,561 (16.7)
Area-level quantitative variables (unstandardized value)	Mean (standard deviation)	Minimum	Maximum
Animal husbandry farm density (/1000 persons)	0.51 (2.89)	0.00	58.30
Crop farm density (/1000 persons)	16.76 (82.37)	0.00	1821.40
Amount of rain fall (mm/year)	1533.51 (228.93)	829.75	2829.45
Mean slope angle (%)	7.19 (10.15)	0.00	73.11

help clarify these seemingly inconsistent results as we found that the prevalence of depressive symptoms in farmers and non-farmers tends to be more similar where farm density is high, compared to where farm density is low. This suggests that it may be beneficial for future studies to examine the farming context e.g. neighborhood environmental factors such as farm density in order to better understand farmers' mental health and the factors associated with it.

The higher prevalence of depressive symptoms among farmers in neighborhoods with a low farm density may reflect a scarcity of formal and informal social support in such communities. Farmers who live in a location where there are few other farmers may have less opportunity to talk about common concerns, such as farm management and family issues. Having access to neighbors/friends who can give and receive social support may be protective against depression [41], as well as promote access to health care [42]. Previous research has shown that a sense of belonging to a community may also affect a farmer's mental health and wellbeing [9, 43]. In general, in Japan the farming community tends to engage in various local activities such as staging festivals and holding various events, as well as undertaking welfare activities for older adults. However, an earlier government report showed that farming communities with a small number of farms tended to have fewer of these local activities [44]. As the number of farms has declined in recent years, it is likely that the number of these local activities may have also correspondingly decreased for farmers in many parts of Japan, resulting in fewer opportunities for farmers to obtain emotional or instrumental social support from their neighbors.

It is worth noting that among men, the prevalence of depressive symptoms in relation to neighborhood animal husbandry farm density differed between farmers and non-farmers, although this result should be interpreted with caution given that there is an elevated risk of a Type I error occurring when evaluating the p value of interaction terms [45]. The higher risk of depressive symptoms in animal husbandry farmers compared to non-farmers in areas with few animal husbandry farms suggests that the potential effect of farm density on depressive symptoms may differ according to occupation. In particular, it is possible that animal husbandry farmers face an especially complex and potentially stressful range of responsibilities and duties [16, 46] including promoting sustainability related to the environment, ensuring animal welfare, and reducing the smell produced by livestock, which might increase the risk for poorer mental health. Moreover, community understanding of the difficulties faced by those engaging in animal husbandry might be lower where animal husbandry farming is less common. Under these circumstances those managing farms might be especially vulnerable to the effects of stress and pressure resulting from their work demands, and this may have contributed to the increased risk of having poor mental health [47]. The fact that more than 90% of farm managers in Japan are men [48] might also help explain why the cross-interaction effect was only observed among men. Furthermore, in this study, we examined farm density, which ignores the size of each farm. Even if an area contained a mega farm, it might still have been more appropriate to categorize it as having a "low" farm density. This is because animal husbandry has dramatically modernized in Japan in recent years, with a reduction in the number of farmers while the quantity of livestock has significantly increased [49]. Although we could not actually quantify the size of the individual farms in each area, these potential health effects of structural change in farm management on individual farmers and the neighborhood environment should be further researched.

Strengths and limitations

Our study has notable strengths. It used data from a large sample in Japan, which enabled us to examine the health status of farmers, whose numbers are small relative to the overall population size. In addition, the richness of the data allowed us to use multilevel models to

Table 2 Prevalence ratios [95% confidence intervals] of depressive symptoms among men: the results of a multilevel analysis

	Null	Model 1		Model 2	
Animal husbandry farm density[a]		1.00	[0.97,1.03]	1.00	[0.97,1.03]
Crop farm density[a]		0.97	[0.93,1.01]	0.97	[0.93,1.01]
Population density quintile (ref. highest)					
High		1.00	[0.95,1.06]	1.00	[0.95,1.06]
Middle		0.99	[0.92,1.06]	0.99	[0.92,1.06]
Low		0.98	[0.91,1.06]	0.98	[0.90,1.06]
Lowest		1.04	[0.93,1.16]	1.04	[0.93,1.16]
Area (ref. Tokai)					
Hokkaido		0.97	[0.82,1.14]	0.97	[0.82,1.14]
Tohoku		1.20	[1.06,1.37]	1.20	[1.06,1.37]
Hokuriku		1.10	[0.98,1.22]	1.10	[0.98,1.22]
Kanto and higashiyama		1.07	[0.99,1.15]	1.07	[1.00,1.15]
Kinki		1.22	[1.11,1.34]	1.22	[1.11,1.34]
Kyushu		1.12	[0.98,1.29]	1.12	[0.98,1.29]
Daylight hours tertile (ref. short)					
Middle		1.00	[0.96,1.06]	1.01	[0.96,1.06]
Long		1.07	[0.99,1.15]	1.07	[0.99,1.15]
Amount of rainfall[a]		1.00	[0.96,1.05]	1.00	[0.96,1.05]
Mean slope angle[a]		0.97	[0.95,1.00]	0.97	[0.95,0.99]
Individual-level factors					
Age (ref. 65–74)					
75–84		1.04	[1.01,1.07]	1.04	[1.01,1.07]
> = 85		1.19	[1.12,1.26]	1.19	[1.12,1.26]
Education: > 9 years (Ref. <=9 years)		1.28	[1.24,1.32]	1.28	[1.24,1.32]
Equivalized household income tertile (Ref. high)					
Middle		1.65	[1.58,1.72]	1.65	[1.58,1.72]
Low		2.33	[2.21,2.46]	2.33	[2.21,2.46]
Living alone: yes (ref. no)		1.49	[1.40,1.58]	1.49	[1.40,1.58]
Having spouse: no (ref: yes)		1.42	[1.36,1.50]	1.42	[1.36,1.50]
Longest occupation: farmer (ref: non-farmer)		1.04	[0.95,1.14]	1.04	[0.93,1.16]
Farmer x animal husbandry farm density		0.96	[0.92,1.01]		
Farmer x crop farm density				0.97	[0.89,1.05]
Random-effect part of the model (contextual effects)					
Between municipality variance[b]	0.016 (0.004)	0.003 (0.002)		0.003 (0.002)	
Median Rate Ratio	1.13	1.05		1.05	
Between neighborhood variance[b]	0.002 (0.002)	0.000 (0.000)		0.000 (0.000)	
Median Rate Ratio	1.04	1.00		1.00	

[a]Per 1 standard deviation unit increase in population
[b]Standard error in parentheses

shed light on potential neighborhood-level factors affecting individual health. The linking mechanisms we discuss in this paper between farm density and depression might also be applicable in other countries. A focus on the health impact of neighborhood farm density, examined as a consequence of structural change in the agricultural sector, may stimulate further research as there is little evidence on this phenomenon at present.

This study also has several limitations that should be noted. First, as the dataset we used was not representative of the whole of Japan, our findings might have limited generalizability because of the coverage of the sampling

Table 3 Prevalence ratios [95% confidence intervals] of depressive symptoms among women: the results of a multilevel analysis

	Null	Model 1		Model 2	
Animal husbandry farm density[a]		1.02	[0.99,1.05]	1.02	[0.99,1.05]
Crop farm density[a]		0.97	[0.94,1.00]	0.97	[0.94,1.00]
Population density quintile (ref. highest)					
High		1.01	[0.97,1.06]	1.01	[0.97,1.06]
Middle		1.06	[1.01,1.11]	1.06	[1.01,1.11]
Low		1.04	[0.96,1.14]	1.04	[0.96,1.13]
Lowest		1.07	[0.98,1.15]	1.07	[0.98,1.15]
Area (ref. Tokai)					
Hokkaido		1.05	[0.85,1.28]	1.05	[0.85,1.29]
Tohoku		1.39	[1.19,1.64]	1.39	[1.19,1.63]
Hokuriku		1.19	[1.07,1.33]	1.19	[1.07,1.33]
Kanto and higashiyama		1.15	[1.06,1.25]	1.15	[1.06,1.25]
Kinki		1.11	[1.01,1.21]	1.11	[1.01,1.21]
Kyushu		1.14	[0.93,1.39]	1.14	[0.93,1.39]
Daylight hours tertile (ref. short)					
Middle		1.01	[0.94,1.09]	1.01	[0.94,1.09]
Long		1.06	[0.96,1.17]	1.06	[0.96,1.17]
Amount of rainfall[a]		1.02	[0.98,1.06]	1.02	[0.98,1.06]
Mean slope angle[a]		0.98	[0.96,1.00]	0.98	[0.96,1.00]
Individual-level factors					
Age (ref. 65–74)					
75–84		1.02	[0.98,1.06]	1.02	[0.98,1.06]
> = 85		1.30	[1.22,1.39]	1.30	[1.22,1.39]
Education: > 9 years (Ref. <=9 years)		1.24	[1.20,1.29]	1.24	[1.20,1.28]
Equivalized household income tertile (Ref. high)					
Middle		1.49	[1.43,1.54]	1.49	[1.43,1.55]
Low		2.09	[1.98,2.19]	2.09	[1.98,2.19]
Living alone: yes (ref. no)		1.13	[1.07,1.20]	1.13	[1.07,1.20]
Having spouse: no (ref: yes)		1.14	[1.11,1.18]	1.14	[1.11,1.18]
Longest occupation: farmer (ref: non-farmer)		1.07	[0.97,1.18]	1.11	[0.96,1.30]
Farmer x animal husbandry farm density		0.98	[0.92,1.04]		
Farmer x crop farm density				0.94	[0.85,1.05]
Random-effect part of the model (contextual effects)					
Between municipality variance[b]	0.023 (0.006)	0.006 (0.002)		0.006 (0.002)	
Median Rate Ratio	1.16	1.08		1.08	
Between neighborhood variance[b]	0.000 (0.000)	0.000 (0.000)		0.000 (0.000)	
Median Rate Ratio	1.00	1.00		1.00	

[a]Per 1 standard deviation unit increase in population
[b]Standard error in parentheses

frame. However, as the JAGES dataset includes residents who live in various types of urban and rural municipalities across Japan, we believe that the findings of this study are applicable to a large degree to healthy older adults nationwide. Second, for individual occupation, we could only obtain information on whether the longest occupation was farmer or not, we could not distinguish the types of agriculture each participant engaged in. For example, we could not determine whether animal husbandry farmers or crop farmers had mental health problems in neighborhoods with a low animal husbandry farm density. This may have biased the findings of our study. Third, the longest occupation variable did not

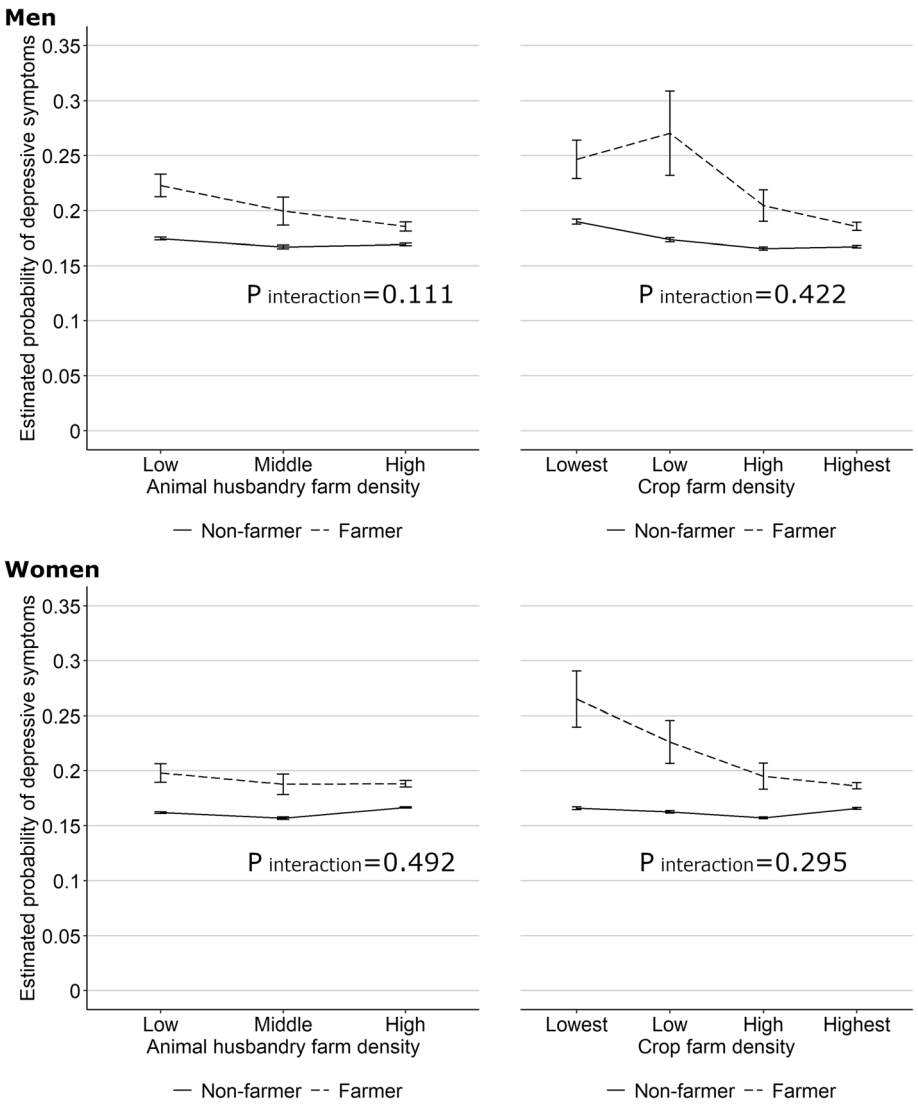

Fig. 1 Estimated probability of depressive symptoms with 95% confidence intervals (error bars) by gender: interaction between types of agriculture in the community and longest occupation (farmer or not). The estimates were derived from a three-level multilevel Poisson regression analysis adjusted for age, education, income, living alone, marital status (having a spouse or not), animal husbandry farm density, crop farm density, daylight hours tertile, amount of rainfall, mean slope angle, population density quintile, and area

include current occupational status. This means that some of the participants who answered that their longest occupation was farmer may have already stopped farming and left their farms. Future research should examine mental health differences between retired farmers and those still working. Fourth, as the data were self-reported it is possible that this may have given rise to various forms of bias such as recall bias and social desirability bias. For example, masculine norms may affect the reporting of mental health problems [8], so the higher prevalence ratios of depressive symptoms observed among male farmers might nevertheless have still been underestimated.

Conclusions

The results of this study suggest that the mental health of individuals whose longest occupation was farmer may be potentially affected by the neighborhood farm density. The higher prevalence of depressive symptoms among farmers in neighborhoods with a low farm density may reflect a scarcity of formal and informal social support in such communities. The health effects of the neighborhood environment on farmers, such as farm density, which may vary by the type of agriculture, should be further researched.

Abbreviations
JAGES: Japan Gerontological Evaluation Study; GDS: Geriatric Depression Scale; MRR: Median Rate Ratio

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Authors' contributions
MK conceived the study idea, designed the study, analyzed the data, and drafted the manuscript. MH provided technical support. NK and KK had primary roles in collecting the data. NK helped conceptualize and design the study. AS helped conceptualize and interpret the data. All authors reviewed and revised the manuscript, and have approved the final version for publication.

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Availability of data and materials
The datasets of the Japan Gerontological Evaluation Study, which were used in this research, are available from the corresponding author upon reasonable request. All enquiries should be addressed to the data management committee via e-mail: dataadmin.ml@jages.net. All JAGES datasets have ethical or legal restrictions for public deposition due to the inclusion of sensitive information from the human participants. Following the regulations of local governments which cooperated in the survey, the JAGES data management committee has imposed restrictions upon the data. The government agricultural data used in this study are openly available from the website of the Ministry of Agriculture, Forestry and Fisheries at [www.maff.go.jp/j/tokei/census/shuraku_data/2015/sa], reference number [23].

Declarations

Ethics approval and consent to participate
The JAGES project was approved by the Ethics Committee at the National Center for Geriatrics and Gerontology (992), at Chiba University, Faculty of Medicine (2493), and at the University of Tokyo, Faculty of Medicine (10555). Written informed consent was assumed with the voluntary return of the questionnaire. The ethics committees approved the use of assumed consent upon return of the questionnaire.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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Original Article

Title: Longitudinal association between oral status and cognitive decline by fixed-effects analysis

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Figure: 1
Supplementary tables: 5

Abstract

Background

Although the feasibility of randomized trials for investigating the long-term association between oral health and cognitive decline is low, deriving causal inferences from observational data is challenging. We aimed to investigate the association between poor oral status and subjective cognitive complaints (SCC) using fixed-effects model to eliminate the confounding effect of unobserved time-invariant factors.

Methods

We used data from Japan Gerontological Evaluation Study (JAGES) which was conducted in 2010, 2013, and 2016. β regression coefficients (95% confidence intervals) were calculated using fixed-effects models to determine the effect of deteriorating oral status on developing SCC. Onset of SCC was evaluated using the Kihon Checklist-Cognitive function score. Four oral status variables were used: awareness of swallowing difficulty, decline in masticatory function, dry mouth, and number of teeth.

Results

13,594 participants (55.8% women) without SCC at baseline were included. The mean age was 72.4 (SD = 5.1) for men and 72.4 (SD=4.9) for women. Within the 6-year follow-up, 26.6% of men and 24.9% of women developed SCC. The probability of developing SCC was significantly higher when participants acquired swallowing difficulty (β= 0.088; 0.065-0.111 for men, β= 0.077; 0.057-0.097 for women), decline in masticatory function (β=0.039; 0.021-0.057 for men, β= 0.030; 0.013-0.046 for women), dry mouth (β= 0.026; 0.005-0.048 for men, β= 0.064; 0.045-0.083 for women), and tooth loss (β= 0.043; 0.001-

0.085 for men, β= 0.058; 0.015-0.102 for women).

Conclusions

The findings suggest that good oral health needs to be maintained to prevent the development of SCC, which increases the risk for future dementia.

Key words: oral health, number of teeth, oral function, cognitive decline, dementia

INTRODUCTION

Approximately 50 million individuals are currently living with dementia worldwide [1]. The number of cases is estimated to rise to 152 million by 2050. A total of 28.8 million disability-adjusted life years have been attributed to dementia [2]. Mild cognitive impairment (MCI) has been identified as an important precursor of dementia [3]. MCI is defined as the intermediate state of cognitive function between the changes seen in aging and those fulfilling the criteria for dementia and often Alzheimer's disease [1,3]. The prevention of MCI could potentially reduce the incidence of dementia in the future.

Recently, several studies have reported an association between poor oral status and cognitive decline or the onset of dementia [4–8]. There are several possible biomedical and social mechanisms underlying the association between oral status and cognitive decline. Vascular dementia, which is caused by cerebrovascular diseases such as stroke, is the second most prevalent type of dementia [9]. Periodontal inflammation has been associated with an increased risk of cerebrovascular diseases [10]. Furthermore, diabetes is a well-known risk factor for dementia [9]; studies have suggested that inflammation caused by periodontal disease increases the risk of diabetes [11]. Depression is also a risk factor for dementia, and poor oral health is associated with the onset of depression [12]. Reduced physical activity and social isolation are also well-known risk factors associated with the development dementia [9]. These factors are also possibly associated with the oral status because poor oral conditions can impair social interactions and increase homeboundness [13].

Despite the abundance of possible connections between oral status and cognitive decline, determining the causal relationships between them with epidemiological studies is a formidable task. Both oral disease and dementia are chronic diseases with long-term

progression, and experimental studies such as randomized control trials are difficult for investigating the relationship. Therefore, any causal inferences have to be drawn from observational data [14]. However, deducing causal inferences from observational data is challenging because of the bias introduced by unmeasured confounders. Recently, econometric methods are being used increasingly in healthcare research to facilitate the acquisition of robust causal inferences [15]. Fixed-effects models have the ability to diminish the bias caused by even unmeasured time-invariant confounders [14,16]. It is possible that previous observational studies may have overestimated the association between oral health and cognitive decline because of the unmeasured confounding bias. Therefore, we examined the hypothesis that poor oral status could increase the risk of cognitive decline using the fixed-effects model.

METHODS

Data collection

This longitudinal study used data from the Japan Gerontological Evaluation Study (JAGES), an ongoing cohort study for community-dwelling older individuals aged 65 years and above and living in Japan [17]. We used data from three waves of the survey, i.e., the data from 2010 were considered as baseline and data from 2013 and 2016 were considered as follow-up. A postal survey was randomly distributed to 95,827 individuals in 16 Japanese municipalities from August 2010 to January 2012. A total of 62,418 participants responded to the initial (baseline) survey (response rate: 65.1%). Among them, 54,529 participants were linked to 2013 and 2016 survey. However, 15,185 participants were lost to follow-up over the 6-year study period (follow-up rate: 72.1%). A total of 6,148 deaths were observed, and 7,744 participants became ineligible for the

survey because they moved away from the community dwellings. We focused on participants who were functionally independent and did not have subjective cognitive complaints (SCC) at baseline. Therefore, we excluded 580 functionally dependent participants and 8,450 participants with SCC. After excluding participants with invalid responses for the teeth variable, 13,594 participants were included in this analysis. The flowchart is shown in Figure 1.

The outcome variable

We used SCC as the outcome measure in this study. SCC was determined from three questions related to cognitive function in the Kihon Checklist (KCL-CF) [18]. Tomata et al. (2017) reported higher KCF-CF score was related to a higher risk of the onset of dementia [19]. Following questions were included in the KCL-CF.

1. “Do your family or your friends point out your memory loss?”

2. “Do you make a call by looking up phone numbers?”

3. “Do you find yourself not knowing today’s date?”

Participants were asked to answer ‘yes’ or ‘no’ to the above-mentioned questions. Answer ‘yes’ for the 1st and 3rd questions, and answer ‘no’ for the 2nd question was indicative of cognitive decline. Participants with at least one response indicating cognitive decline were considered to have SCC [20].

Explanatory variables

We used swallowing difficulty, decline in masticatory function, dry mouth, and number of teeth as explanatory variables. Swallowing difficulty, decline in masticatory function, and dry mouth were assessed using responses to the following questions, respectively.

1. “Have you often choked on your tea or soup recently?”

2. “Do you have any difficulties eating tough foods compared to 6 months ago?”

3. “Do you often experience having a dry mouth?”

These questions were also a part of the KCL-CF questionnaire [18].

The number of teeth were measured by asking participants, “How many remaining teeth do you have?”. Participants were asked to choose between 4 categories (≥20/10-19/1-9/0) in 2010 and 5 categories (≥20/10-19/5-9/1-4/0) in 2013 and 2016. In this study, 2 category classification for number of teeth (i.e. ≥20/0-19) was used. This categorization was obtained from a previous study [21]. We conducted sensitivity analysis with different number of teeth categories (N=14,830).

Covariates

Potential confounders were selected based on a systematic review [5]. Demographic factors including age (65-69/70-74/75-79/80-84/≥85 years) and marital status (married, living together/single, divorced, or widowed) were recorded. Socioeconomic status was evaluated using the equivalent household income (<1.00/1.00-1.99/2.00-2.99/3.00-3.99/≥4.00 million Japanese Yen) and education level (≤9/10-12/≥13 years of educations). Previous study which used fixed-effects analysis treated educational level as time-invariant variable [16], however, we treated it as time-variant because lifelong learning has become normal in Japan [22]. The equivalent household income was calculated by dividing the annual household income by the square root of the number of family members. Comorbidities included the presence of hypertension (yes/no) and diabetes mellitus (yes/no). Health behaviors included alcohol consumption (current drinker/past drinker/nondrinker), smoking history (current smoker/past smoker/non-smoker), and

daily walking time (<30 minutes/30-59 minutes/60-89 minutes/≥90 minutes). We did not adjust for the history of stroke, depression, social relationship, and the denture use. We considered these variables to be mediators between oral status and cognitive decline because it was reported that poor oral status increased the risk of stroke [23], depression [24] and less communication[25], and the denture use[26].

Statistical analysis

First, the suitability of the fixed-effects models over the random-effects models was confirmed using the Hausman test [27]. A linear probability model with the onset of SCC as the outcome was used to improve interpretability [28,29]. We calculated the β coefficient with a 95% confidence interval (95% CI) to investigate how changes in oral status affected the probability of onset of SCC. The following equation was used to calculate the β coefficients.

Subjective cognitive complaint it = β0 + β1 swallowing difficulty it + β2 masticatory function it + β3 dry mouth it + β4 number of teeth it +βk Xk it + Ai + Uit

The *subjective cognitive complaint* (0,1) of individual "*i*" at a given time "*t*" is the left part of this formula. Four time-variant explanatory variables for the i^{th} individual at time *t* are included on the right side. *Xk* is the matrix of time-variant confounding variables. *Ai* models the fixed-effect, i.e., the effect of unmeasured time-invariant variables such as personal ability. *Uit* is an error term. The β coefficient indicated the degree of the probability of the onset of SCC when oral status increase by one unit, in other words, from 0 (no) to 1 (yes) for oral functions or 0 (≥20 teeth) to 1 (0-19 teeth) for number of teeth.

We found that 3,732 participants responded with a higher value for the number of

teeth than that of the previous wave. We dropped these variables and performed multivariate imputations (MI). We also conducted a sensitivity analysis that excluded the data of participants with 0-19 teeth could not change their dental status over 6 years, which might not have been suitable for the fixed-effects analysis. Therefore, we excluded the data of the participants with 0-19 teeth at baseline for the sensitivity analysis (N=6,666).

Cognitive decline was found to be affected by sex [30]. Therefore, we conducted an analysis stratified by sex. The oral status variables were assessed using separate models because they were highly correlated, especially between severe tooth loss and chewing difficulty [31]. Swallowing difficulty, decline in masticatory function, dry mouth, and number of teeth were separately included separately with the age variable in model 1. Marital status, equivalent household income, education level, presence of hypertension, presence of diabetes mellitus, drinking history, smoking history, and walking time were added in model 2.

We compensated the missing values with the iterative imputation method (missForest) based on a random forest using Python [32]. We conducted MI in a wide data format in line with the recommendations of Young et al. (2015) [33]. We used Stata 15.0 MP (Stata Corporation LP, Texas, USA, Windows version) for all analyses except MI. The reporting of this study conforms to STROBE guidelines.

Ethical approval

The Ethics Committee of the National Center for Geriatrics and Gerontology (approval number: 992), Chiba University (approval number: 2493) and Tohoku University Graduate School of Medicine (21-40) provided ethical approval for the

JAGES. Participants were notified that participation was voluntary and returning a completed survey was considered as consent for enrollment.

RESULTS

Table 1 presents the baseline characteristics of 13,594 participants (6,006 men and 7,588 women) before and after MI. The distribution showed similar before and after MI. The mean age of the participants at baseline was 72.4 (SD = 5.1) years for men and 72.4 (SD=4.9) years for women. The age of the study population ranged from 65 to 96 years at baseline. Table 2 shows the cross-tabulation of the onset of SCC in 2016 by oral status in 2010 and changes in 2010-2016. Within the follow-up period, 26.6% of men and 24.9% of women developed SCC. Participants who reported comparatively lower levels of oral status at baseline and no changes in oral status from 2010 to 2016 tended to have a higher prevalence of SCC in 2016.

Table 3 presents the sex-stratified results of the fixed-effects models generated to predict the onset of SCC. The probability of the onset of SCC was significantly higher when participants acquired swallowing difficulty (β= 0.088; 0.065-0.111 for men, β= 0.077; 0.057-0.097 for women), decline in masticatory function (β=0.039; 0.021-0.057 for men, β=0.030; 0.013-0.046 for women), dry mouth (β= 0.026; 0.005-0.048 for men, β= 0.064; 0.045-0.083 for women) and tooth loss (β= 0.043; 0.001-0.085 for men, β= 0.058; 0.015-0.102 for women). This result can be interpreted as follows. Men who acquired swallowing difficulty demonstrated 8.8% (95% CI 6.5%-11.1%) higher probability of developing SCC on average. The probability was the highest among participants who acquired swallowing difficulty compared to those with a decline in masticatory function, dry mouth, and tooth loss. All other covariate specific coefficients

and 95% CI are presented in eTable.2. and eTable.3.

In the results of both of the sensitivity analysis with a different number of teeth categories and without participants with 0-19 teeth at baseline, the β coefficient of tooth loss was slightly larger than the main analysis. (shown in eTable.4. and eTable.5)

DISCUSSION

To the best of our knowledge, this was the first study to examine the effect of a wider range of oral status variables on SCC using large-panel data, after adjusting for unmeasured time-invariant confounders. The probabilities of the onset of SCC were higher when participants acquired swallowing difficulty [differences in the onset (%) were 8.8% for men, 7.7% for women], decline in masticatory function (3.9% for men, 3.0% for women), dry mouth (2.6% for men, 6.4% for women), and tooth loss (4.3% for men and 5.8% for women) on average. These results are important for understanding the risk of dementia because the SCC was related to the increased risk of incident dementia [19].

The longitudinal association observed between tooth loss and future dementia in this study is consistent with the findings of previous studies [5,6]. We added robust evidence obtained from fixed-effects model, which nullified the confounding effect of unmeasured time-invariant variables. Our findings related to masticatory function were consistent with those of previous systematic reviews [4,7]. Earlier studies have suggested that patients with dementia tended to have dysphagia [34] and dry mouth [35], however, no study has examined the longitudinal association between swallowing difficulty or dry mouth and the onset of SCC among the community-dwelling older adults.

Several plausible mechanisms are underlying the association between poor oral

status and cognitive decline. First, the deterioration in oral status affects the quality of social activities such as speaking and smiling. Tooth loss and deterioration of oral status can predict future homeboundness among the older population [13]. Physical inactivity and social isolation are major risks for dementia [9]. Second, a deteriorating oral condition could increase the risk of depression due to the lack of social activities [13,36], subsequently increasing the risk of dementia [9]. Third, the decline of oral status could lead to malnutrition, which is a possible cause of cognitive decline among older adults [37]. Those with dry mouth tend to avoid dry food such as bread and vegetable [38]. Swallowing difficulty causes malnutrition because they reduce or alter food intake from solids to liquids [39]. A previous study has shown that vitamin deficiency partially explains the association between malnutrition and cognitive decline [40]. Furthermore, an association between nutritional biomarkers at baseline and cognitive decline at follow-up has also been reported [41]. Fourth, the decline in oral status might be related to cognitive decline through diminished cerebral blood flow. A systematic review that examined the results of biological experiments suggested that masticatory function may play a protective role in maintaining cognitive function [7]. Finally, the inflammatory pathway of periodontal diseases might be related to cognitive decline [42]. Cytokines produced by periodontal inflammation could enter the systemic circulation, which may contribute to cognitive decline [42].

We provided evidence of the importance of maintaining good oral health as implication. Public health interventions that focus on the prevention of dental caries and periodontal diseases, which are the major causes of tooth loss [43], are essential. These interventions are also aid in maintaining masticatory function [31]. The use of several medications can lead to dry mouth, which is a concern in the medical field [44]. Therefore,

reducing any unnecessary medications is required via cooperation with medical doctors.

This study has several strengths. First, we used data from a large-scale cohort from rural and urban areas of Japan. Moreover, the follow-up rate for all participants was relatively high (72.1%). Second, we used fixed-effects analysis, which enabled the reduction of the bias introduced by unobserved time-invariant confounders, such as individual personalities or abilities for keeping oral hygiene [27]. The limitation of the study is that the fixed-effects model cannot control for unobserved time-variant variables [27]. However, we adjusted the models using various time-variant covariates. Second, fixed-effects models cannot determine reverse causality [27]. However, we restricted the target population to individuals without SCC at baseline. Therefore, it is unlikely that participants with cognitive impairment would have poor oral status. Third, we used a self-reported questionnaire that relied on subjective answers. Tomata et al mentioned only KCF-CF score is not sufficient for predicting dementia due to a false-negativity rate of KCF-CF [19]. Therefore, more validated questionnaire would be expected. For explanatory variables, the self-reported number of teeth is a reliable measurement [45] and several studies commonly used [21,24]. We assessed the swallowing difficulty by obtaining a single question. Currently, EAT-10, the validated self-reported questions were introduced [46]. Although a single question was used in several studies [47–49], future studies should consider multiple questionnaires such as EAT-10. Additionally, we asked the participants about dry mouth by a single question. A visual analog scale measure would be a better predictor for detecting dry mouth [50].

Fourth, our data excluded participants who were certified as having dementia by the city government or died during the follow-up year. We think that the longitudinal association between oral health and the onset of SCC would have been stronger if we had

included individuals with dementia or who died in our analysis.

CONCLUSION

The decline in oral status (swallowing difficulty, decline in masticatory function, dry mouth, and tooth loss) was significantly associated with the onset of SCC after adjusting for time-invariant confounding factors. The present findings show the importance of keeping good oral health for preventing SCC, which is related with higher risk of dementia.

Conflicts of interest: The authors have no conflicts of interest to declare.

Authors' contributions:

Conceptualization: SK and JA. Data curation: SK and JA. Formal analysis: SK, TK, UC, JA. Writing-original draft: SK and JA. Writing-review& editing: TK, KS, TY, UC, TY, KK, KO. Supervision: KS, TY, TY, KK, KO, JA. All authors read and approved the final version of manuscript.

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Appendix

eTable.1. Descriptive baseline characteristics of the participants who did not have any subjective cognitive complaint (2010) with missing values (N=13,594)

eTable.2. Probability of the onset of subjective cognitive complaints (95% confidence interval) by oral status among men using fixed-effects linear regression analysis from the data of 2010, 2013, 2016 panels (N= 6,006)

eTable.3. Probability of the onset of subjective cognitive complaints (95% confidence interval) by oral status among women using fixed-effects linear regression analysis from the data of 2010, 2013, 2016 panels (N= 7,588)

eTable.4. Probability of the onset of subjective cognitive complaints (95% confidence interval) by oral status with different number of teeth categories using fixed-effects linear regression analysis from the data of 2010, 2013, 2016 panels (N=14,830)

eTable.5. Probability of the onset of subjective cognitive complaints (95% confidence

interval) by oral status without participants who responded with 0-19 teeth at baseline using fixed-effects linear regression analysis from the data of 2010, 2013, 2016 panels (N=6,666)

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Figure Legends

Figure 1. The flowchart of the participants for the analysis

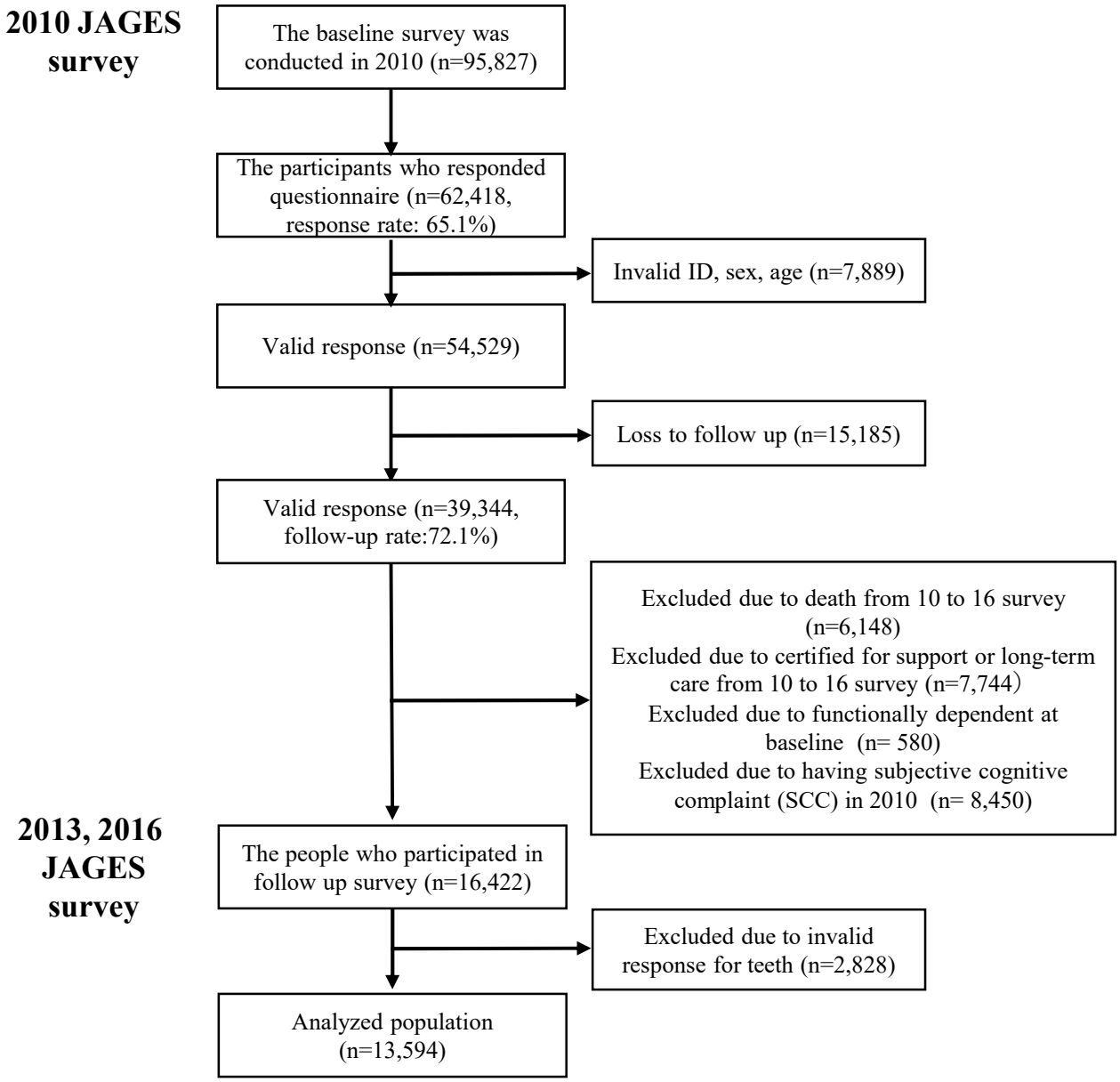
2010 JAGES survey
The baseline survey was conducted in 2010 (n=95,827)
The participants who responded questionnaire (n=62,418, response rate: 65.1%)
Invalid ID, sex, age (n=7,889)
Valid response (n=54,529)
Loss to follow up (n=15,185)
Valid response (n=39,344, follow-up rate:72.1%)
Excluded due to death from 10 to 16 survey (n=6,148)
Excluded due to certified for support or long-term care from 10 to 16 survey (n=7,744)
Excluded due to functionally dependent at baseline (n= 580)
Excluded due to having subjective cognitive complaint (SCC) in 2010 (n= 8,450)
2013, 2016 JAGES survey
The people who participated in follow up survey (n=16,422)
Excluded due to invalid response for teeth (n=2,828)
Analyzed population (n=13,594)

Figure 1.

Table 1: Descriptive baseline characteristics of the participants who did not have any subjective cognitive complaint (2010) (N=13,594)

		Men (N=6,006)	Women (N=7,588)
Explanatory variable		%	%
Swallowing difficulty	No	89.0	89.4
	Yes	11.0	10.6
Decline in masticatory function	No	80.1	80.5
	Yes	19.9	19.5
Dry mouth	No	85.3	86.4
	Yes	14.7	13.6
Number of teeth	≥20	49.1	49.0
	0-19	50.9	51.0
Covariates			
Age (years)	65-69	35.1	33.9
	70-74	33.5	35.6
	75-79	20.9	21.3
	80-84	8.4	7.5
	≥85	2.0	1.7
Marital status	Single, Divorced, Widowed	11.0	35.2
	Married, Living together	89.0	64.8
Income (million Japanese yen)	<1.00	6.8	14.3
	1.00-1.99	33.8	34.1
	2.00-2.99	29.0	27.5
	3.00-3.99	17.9	13.6
	≥4.00	12.5	10.4
Educational level (years)	≤9	37.0	46.5
	10-12	35.4	38.7
	≥13	27.5	14.7

Hypertension	No	56.8	54.4
	Yes	43.2	45.6
Diabetes mellitus	No	85.9	90.8
	Yes	14.1	9.2
Drinking history	Current drinker	61.8	16.7
	Past drinker	4.2	0.8
	Non-drinker	34.0	82.5
Smoking history	Current smoker	17.8	2.7
	Past smoker	55.4	4.2
	Non-smoker	26.8	93.0
Walking time	<30 minutes	24.2	28.6
	30-59 minutes	37.2	37.7
	60-89 minutes	19.0	15.9
	≥90 minutes	19.6	17.7
Total		100.0	100.0

Note: The descriptive characteristics shown here used imputed datasets.

Table 2: The cross-tabulation of the onset of subjective cognitive complaint in 2016 by oral health status in 2010 and changes in 2010-2016 (N=13,594)

			Men			Women	
		Total	No	Yes	Total	No	Yes
		N	%	%	N	%	%
Oral status in 2010							
Swallowing difficulty	No	5,345	74.4	25.6	6,786	75.9	24.1
	Yes	661	64.8	35.2	802	68.5	31.5
Decline in masticatory function	No	4,813	75.4	24.6	6,105	76.7	23.3
	Yes	1,193	65.1	34.9	1,483	68.7	31.3
Dry mouth	No	5,124	75.1	24.9	6,555	76.2	23.8
	Yes	882	63.3	36.7	1,033	68.5	31.5
Number of teeth	≥20	2,949	75.8	24.2	3,717	77.1	22.9
	0-19	3,057	71.0	29.0	3,871	73.2	26.8
Changes in oral status in 2010-2016							
Swallowing difficulty	Improve	287	67.6	32.4	346	73.4	26.6
	No change	5,092	75.5	24.5	6,407	76.6	23.4
	Decline	627	58.4	41.6	835	64.9	35.1
Decline in masticatory function	Improve	448	71.4	28.6	522	71.6	28.4
	No change	4,555	74.7	25.3	5,874	76.6	23.4
	Decline	1,003	68.3	31.7	1,192	69.6	30.4
Dry mouth	Improve	432	66.7	33.3	409	71.6	28.4
	No change	4,945	74.9	25.1	6,270	76.6	23.4
	Decline	629	66.1	33.9	909	66.3	33.7
Number of teeth	No change	5,613	73.4	26.6	7,243	75.2	24.8
	Decline	393	73.0	27.0	345	73.0	27.0
Total		6,006	73.4	26.6	7,588	75.1	24.9

Table 3: Probability of the onset of subjective cognitive complaints (95% confidence interval) by oral status using fixed-effects linear regression analysis from the data of 2010, 2013, 2016 panels (N=13,594)

	Model 1		Model 2	
Men (N=6,006)	β	95% CI	β	95% CI
Swallowing difficulty	0.089	(0.066-0.112)***	0.088	(0.065-0.111)***
Decline in masticatory function	0.037	(0.019-0.055)***	0.039	(0.021-0.057)***
Dry mouth	0.025	(0.003-0.046)*	0.026	(0.005-0.048)*
Tooth loss[a]	0.042	(0.000-0.084)*	0.043	(0.001-0.085)*
Women (N=7,588)				
Swallowing difficulty	0.077	(0.058-0.097)***	0.077	(0.057-0.097)***
Decline in masticatory function	0.030	(0.014-0.046)***	0.030	(0.013-0.046)***
Dry mouth	0.065	(0.047-0.084)***	0.064	(0.045-0.083)***
Tooth loss[a]	0.062	(0.019-0.106)**	0.058	(0.015-0.102)**

Model 1: Swallowing difficulty, decline in masticatory function, dry mouth and tooth loss were separately included in the models with age.

Model 2: Model 1 + marital status, income, education level, hypertension, diabetes mellitus, drinking history, smoking history, and walking time.

[a] Reference category: ≥20

Abbreviations: CI, confidence interval

*p< 0.05

**p< 0.01

***p<0.001

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Association between Proximity of the Elementary School and Depression in Japanese Older Adults: A Cross-Sectional Study from the JAGES 2016 Survey

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Abstract: Depression among older adults is one of the most critical public health issues. The proximity of elementary schools has been positively associated with neighborhood social cohesion and quality of life. However, no studies have identified an association between the proximity of elementary school and older adults' mental health. Therefore, this study aimed to examine the association between the proximity of elementary schools, one of the core facilities of neighborhood communities in Japan, and depression in older adults. A total of 131,871 participants (63,430 men 73.7 ± 6.1 years, 68,441 women 73.8 ± 6.2 years) were analyzed from the Japan Gerontological Evaluation Study (JAGES) 2016 survey. Logistic regression analysis showed that there was no association between distance to elementary school and depression among males. However, among females, compared with the participants living within 400 m from the nearest elementary school, the odds ratio of depression for those living between 400 and 799 m and more than 800 m away were 1.06 (95% confidence interval (CI) 1.00–1.12) and 1.07 (95% CI 1.00–1.15), respectively. The findings may be useful when considering the design of communities around elementary schools and the planning of facilities as a population-based approach to promote mental health of older women.

Keywords: older adults; depression; neighborhood environment; elementary school proximity; intergenerational exchange; age-friendly cities; Japan

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1. Introduction

The incidence of depression is increasing worldwide, and a World Health Organization (WHO) report estimated that more than 300 million people, equivalent to 4.4% of the world's population, had depression in 2017. The total population with depression increased by 18.4% between 2005 and 2015 [1], and its prevalence is exceptionally high among older adults [1]. The age-standardized incidence of depression worldwide is also increasing in regions with higher sociodemographic indicators [2]. Depression significantly reduces the quality of life and increases the risk of suicide, dementia, functional decline, elder abuse, and disability in older adults [3–7], and constitutes a significant public health issue.

In 2006, the WHO advocated for primordial prevention by recommending a change of attitudes, behaviors, and social values, which can be achieved by encouraging positive health behaviors, preventing the adoption of risk behaviors, eliminating established risk behaviors, and promoting the concept of health as a social good [8]. Primordial prevention requires a population-based approach, which targets the whole population irrespective of the risk level, and this is different from the high-risk approach, which focuses only on individuals or population groups with the highest risk of disease. In addition, it must confront

the social, cultural, and community aspects of increased risk. Moreover, population-based approaches achieve considerably greater health gains than high-risk approaches due to the larger number of people involved [9].

These trends have intensified research on neighborhood environments that improve health [9,10]. There are many reports on the relationship between neighborhood environment and physical health, such as the impact of parks, sidewalks, or other built environments on physical activity and obesity rates [11,12]. There have also been studies on how the neighborhood environment affects mental health in older adults [13]. For example, the neighborhood built environment comprising high walkability, better access to transportation and destinations, better street connectivity, traffic safety, large amount of greenspace, and the social environment, such as high local social capital, is possibly related to improved mental health in older adults [14–19].

To develop a healthy neighborhood environment, the WHO has published the age-friendly cities guide that promotes active aging of older adults [20]. This guideline has indicators such as the accessibility of destinations, traffic safety, and social inclusion, and recommends the use of community facilities such as schools and recreation centers by all community members, including older adults, to help them participate in community activities and intergenerational exchange [21]. This implies that elementary schools can be considered components of age-friendly cities.

However, the relationship between elementary schools and the health of older adults has not been sufficiently studied. For example, the proximity to an elementary school, which represents the distance between the elementary school and the place of residence, has been shown to enhance neighborhood social cohesion as a place for increased interaction and group activities, improved quality of life, and increased children's physical activity [22–26]. These participants may encompass the entire population of residents, including older adults and children. Furthermore, none of the previous studies examined the relationship between proximity to an elementary school and older adults' health, particularly depression.

Therefore, we hypothesized that proximity to an elementary school might be associated with improved mental health of older adults. In Japan, elementary schools are one of the core facilities of a neighborhood community and are often used for local events, such as elections and athletic events, which may enhance social capital that is said to be associated with the health of individual or community health. In addition, the vicinity of the elementary schools may influence the safety of elementary school children on their way to and from school. Furthermore, people residing near elementary schools have many potential opportunities for daily contact with children, such as seeing, hearing, and talking to elementary school students on their way to and from school, which may promote intergenerational exchange. The purpose of this study was to examine the relationship between proximity to elementary schools and depression among Japanese older adults.

2. Methods

2.1. Population and Settings

This study used cross-sectional data from the Japanese Gerontological Evaluation Study (JAGES) conducted in 2016 [27]. JAGES is an epidemiological research-based project conducted every 3 years from 2010 and focuses on older adults from different regions across Japan. It aims to build scientific evidence on the role of preventive medicine in a healthy aging society. Participants were older adults in a community (age ≥65 years) who did not have physical or cognitive disabilities and had not received a certification of long-term care [27,28]. Thirty-nine municipalities in 19 prefectures across Japan participated in this research project. The survey was a self-administered questionnaire that was returned by postal mail from October 3 to December 5, 2016. The questionnaire forms were distributed to participants via the local government. Although the local governments were not randomly selected, they covered a wide range of characteristics in terms of region and population size in Japan. The questionnaire examined health status,

psychological status, social support, social participation, hobbies, frequency of outings, life habitats, and demographic information, including sex, age, education level, equivalent income (annual household income), marital status, living arrangement, self-reported socioeconomic status, etc. A total of 180,021 data points (response rate: 70.2%) were identified in 2016. We excluded older adults who did not live independently with regards to their daily living based on their response to the following questions evaluating independence of activities of daily living (ADLs): "Do you regularly receive care and assistance for walking, bathing, toileting, etc.?"; the responses included (1) does not need care or assistance, (2) needs care or assistance but does not receive it, and (3) needs care or assistance but does receive it. We defined (3) as being dependent for activities of daily living [29]. A total of 131,871 individuals without missing data for the outcome (i.e., depression) and residential information for the explanatory variables were included in the analysis.

2.2. Outcome Variable

The outcome variable was depression. A short version of the Geriatric Depression Scale (GDS-15) was used to identify depression, which was indicated by a GDS-15 score of 5 or more in this study [30,31].

2.3. Explanatory Variable

The explanatory variable was the distance from the respondents' place of residence to the nearest elementary school. For accuracy, we used the latitude and longitude of a representative point in the city-level location reference information provided by the Ministry of Land, Infrastructure, Transport and Tourism, rather than the respondent's residence address. The network distance from the representative point of the respondent's residence to the nearest elementary school was calculated using ArcGIS ver. 10.3.1 (Esri, Redlands, CA, USA) [32]. The network distances were categorized into four groups for every 400 m (<400, 400–799, 800–1199, and ≥1200 m). The 400-m category was determined on the basis of prior literature and guidelines on the proximity to the destinations [33–35]. Walking distance within five minutes of walking time was often represented by a radius measuring 400 m among urban planners [36]. The neighborhood concept proposed by Clarence Stein also suggests that elementary schools should be located at the center of neighborhood units within a 400-m walking distance of all residents [37].

2.4. Covariates

According to the covariates that were evaluated in previous studies, we used basic demographic information, including sex (male/female), age (65–69, 70–74, 75–79, 80–84, or ≥85 years), education level (≤9, ≥10 years, or missing), equivalent income (low: ≤1.9; middle: 2.0–3.9; high: ≥4 million yen/year; and missing), marital status (married, unmarried, others, missing), employment status (employed, unemployed, or missing), and family structure (living alone, living with a family member, others (e.g., living in institutional care or missing)) as covariates [38–40]. Furthermore, we added the frequency of outings (>4 times a week, 1–3 times a week, 1–3 times a month, less than a few times a year, or missing), driving habits (no driving or driving), and frequency of meeting friends (>4 times a week, 1–3 times a week, 1–3 times a month, less than a few times a year, or missing) as covariates as these were previously reported to be associated with depression [41,42]. House-owned status (owned, rented or otherwise, or missing) and duration of residence (<20, 20, 20–39, 40–59, 60–79, ≥80 years, and missing) were added as variables that could be assumed as confounders of residence and depression [43,44]. To adjust for urbanity, the township population density was added to the covariate as quintiles [45,46].

2.5. Statistical Analysis

Descriptive statistics were used to summarize the participants' characteristics, their number, and the sex-stratified percentage of subjects for each variable. Chi-square tests were

used to report sex-related differences for each variable. Logistic regression analysis was performed to investigate the association between depression and accessibility to the elementary school. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated by sex because of the possibility of sex-related differences in descriptive statistics. Stata 16.1/IC (StataCorp, College Station, TX, USA) was used for all statistical analyses.

3. Results

Table 1 shows the sex-stratified results of the descriptive statistics of the 131,871 individuals. The incidence of depression was higher in males than in females (22.9% and 22.3%, respectively, $p < 0.001$). Among the older adults, 15.2% lived near an elementary school (<400 m), and there were no sex-related differences in the proximity to an elementary school. The percentage of the target population of females (51.9%) was higher than that of males (48.1%). The results of the chi-square test showed that a higher proportion of males had more than 10 years of education (70.5% of male participants and 64.4% of female participants, $p < 0.001$) and employment (31.4% male participants and 20.1% female participants, $p < 0.001$). Moreover, men were more likely to be married (84.8% of males and 61.6% of females, $p < 0.001$) and less likely to live alone (37.9% of males and 48.9% of females, $p < 0.001$). A higher percentage of male participants drove cars than female participants (76.1% and 40.1%, respectively, $p < 0.001$). Regarding psychosocial factors, female participants tended to meet with friends more frequently than the male participants (more than once a week: 48.9% and 37.9%, respectively, $p < 0.001$).

Table 1. Sex-stratified descriptive statistics for the total study population.

Characteristics	Male n = 63,430	Female n = 68,441	χ^2 Value (df)
Depression, n (%)			7.3 (1) **
Normal	48,896 (77.1%)	53,184 (77.7%)	
Depression	14,534 (22.9%)	15,247 (22.3%)	
Distance to elementary school, m, n (%)			1.4 (3)
<400	9533 (15.0%)	10,402 (15.2%)	
400–799	21,491 (33.9%)	23,239 (34.0%)	
800–1199	17,727 (27.9%)	18,955 (27.7%)	
≥1200	14,679 (23.1%)	15,845 (23.2%)	
Population density, person/km^2, n (%)			16.0 (3) **
<1119	15,325 (24.2%)	16,934 (24.7%)	
1119–4985	15,842 (25.0%)	17,200 (25.1%)	
4986–9377	16,332 (25.7%)	17,000 (24.8%)	
≥9378	15,931 (25.1%)	17,307 (25.3%)	
Age group, years, n (%)			11.9 (4) *
65–69	20,322 (32.0%)	21,471 (31.4%)	
70–74	17,206 (27.1%)	18,611 (27.2%)	
75–79	13,869 (21.9%)	15,358 (22.4%)	
80–84	8214 (12.9%)	8757 (12.8%)	
≥85	3819 (6.0%)	4244 (6.2%)	
Education level, years, n (%)			584.7 (2) ***
≤9	18,142 (28.6%)	23,378 (34.2%)	
≥10	44,718 (70.5%)	44,081 (64.4%)	
Missing	570 (0.9%)	982 (1.4%)	
Equivalent income, million yen/year, n (%)			1188.9 (3) ***
Low (≤1.9)	24,660 (38.9%)	26,325 (38.5%)	
Mid (2–3.9)	22,086 (34.8%)	20,242 (29.6%)	
High (≥4)	6495 (10.2%)	6036 (8.8%)	
Missing	10,189 (16.1%)	15,838 (23.1%)	

Table 1. Cont.

Characteristics	Male n = 63,430	Female n = 68,441	χ^2 Value (df)
Marital status, n (%)			9297.9 (3) ***
Married	53,790 (84.8%)	42,190 (61.6%)	
Unmarried	8617 (13.6%)	25,086 (36.7%)	
Others	457 (0.7%)	422 (0.6%)	
Missing	566 (0.9%)	743 (1.1%)	
Work status, n (%)			3559.3 (2) ***
Employed	19,901 (31.4%)	13,740 (20.1%)	
Unemployed	37,341 (58.9%)	41,791 (61.1%)	
Missing	6188 (9.8%)	12,910 (18.9%)	
Living arrangement, n (%)			2735.6 (3) ***
Living alone	6247 (9.8%)	12,564 (18.4%)	
With family members	48,700 (76.8%)	44,021 (64.3%)	
Other facilities	5820 (9.2%)	7952 (11.6%)	
Missing	2663 (4.2%)	3904 (5.7%)	
Household status, n (%)			91.1 (2) ***
Owned	55,534 (87.6%)	58,987 (86.2%)	
Rental/others	7464 (11.8%)	8715 (12.7%)	
Missing	432 (0.7%)	739 (1.1%)	
Duration of residence, years, n (%)			4403.8 (5) ***
<20	12,314 (19.4%)	13,174 (19.2%)	
20–39	19,323 (30.5%)	19,698 (28.8%)	
40–59	17,857 (28.2%)	28,011 (40.9%)	
60–79	10,840 (17.1%)	5900 (8.6%)	
≥80	2332 (3.7%)	733 (1.1%)	
Missing	764 (1.2%)	925 (1.4%)	
Outgoing frequency, n (%)			70.0 (4) ***
≥4 times/week	42,713 (67.3%)	44,935 (65.7%)	
1–3 times/week	11,718 (18.5%)	13,249 (19.4%)	
1–3 times/month	1529 (2.4%)	1352 (2.0%)	
A few times/year	320 (0.5%)	250 (0.4%)	
Missing	537 (0.8%)	481 (0.7%)	
Driving habit, n (%)			17,478.5 (1) ***
No	15,170 (23.9%)	41,030 (59.9%)	
Yes	48,260 (76.1%)	27,411 (40.1%)	
Frequency of meeting friends, n (%)			3544.5 (4) ***
≥4 times/week	8474 (13.4%)	11,149 (16.3%)	
1–3 times/week	15,554 (24.5%)	22,331 (32.6%)	
1–3 times/month	12,727 (20.1%)	13,713 (20.0%)	
A few times/year	19,227 (30.3%)	11,898 (17.4%)	
Missing	835 (1.3%)	1176 (1.7%)	

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

The OR and 95% CI for the association between living near an elementary school and depression are shown in Table 2. Among male participants, there was no significant association between distance to the elementary school and the incidence of depression. However, among female participants, compared with the participants who lived less than 400 m away from the nearest elementary school, those who lived 400–799, 800–1199, and >1200 m away were 1.06 (95% CI 1.00–1.12), 1.07 (95% CI 1.00–1.14), and 1.07 (95% CI 1.00–1.15) times, respectively, more likely to have depression. In terms of the association between covariates and depression, the risk of depression was higher for both men and women with lower education and income, no job, unmarried, living alone, not living

in an owned house, and no driving habits. Less frequent going out and seeing friends was associated with a higher risk of depression for both men and women, but this trend was more pronounced in women than in men. Considering age group as a covariate, older age was associated with a lower risk of depression for both men and women aged 70 years and older compared to those aged 65–69 years. The risk of depression has been reported to increase with age, although this trend was reversed when educational history, income, employment, and marital status were included as covariates in this analysis [42,47]. Among the associations between covariates and depression, the trend for men and women differed in duration of residence. Men aged 60 years and older were at a higher risk of depression than those who lived for less than 20 years, but there was no association between duration of residence and depression in women.

Table 2. The sex-stratified association between depression and the explanatory variables.

Characteristics	Male				Female			
	n	OR	95% CI	*p*-Value	*n*	OR	95% CI	*p*-Value
Distance to elementary school, m								
<400	9533	1.00			10,402	1.00		
400–799	21,491	1.01	0.95–1.07	0.773	23,239	1.06	1–1.12	0.059
800–1199	17,727	1.02	0.96–1.09	0.568	18,955	1.07	1–1.14	0.035
≥1200	14,679	1.00	0.93–1.07	0.923	15,845	1.07	1–1.15	0.051
Population density, person/km^2								
<1119	15,325	1.00			16,934	1.00		
1119–4985	15,842	0.92	0.87–0.98	0.006	17,200	0.93	0.87–0.98	0.008
4986–9377	16,332	0.91	0.85–0.97	0.003	17,000	0.88	0.83–0.94	<0.001
≥9378	15,931	0.84	0.78–0.90	<0.001	17,307	0.87	0.81–0.93	<0.001
Age group, years								
65–69	20,322	1.00			21,471	1.00		
70–74	17,206	0.93	0.88–0.98	0.007	18,611	0.94	0.89–0.99	0.024
75–79	13,869	0.91	0.86–0.96	0.001	15,358	0.91	0.86–0.96	0.001
80–84	8214	0.95	0.88–1.01	0.117	8757	0.96	0.90–1.03	0.243
≥85	3819	0.87	0.79–0.95	0.003	4244	0.98	0.90–1.07	0.675
Education level, years								
≤9	18,142	1.00			23,378	1.00		
≥10	44,718	0.75	0.72–0.79	<0.001	44,081	0.80	0.77–0.83	<0.001
Missing	570	0.95	0.78–1.16	0.626	982	0.92	0.79–1.07	0.276
Equivalent income								
Low (≤1.9 million yen/year)	24,660	1.00			26,325	1.00		
Mid (2–3.9 million yen/year)	22,086	0.61	0.59–0.64	<0.001	20,242	0.65	0.62–0.68	<0.001
High (≥4 million yen/year)	6495	0.44	0.40–0.48	<0.001	6036	0.45	0.42–0.50	<0.001
Missing	10,189	0.87	0.82–0.92	<0.001	15,838	0.86	0.82–0.90	<0.001
Marital status								
Married	53,790	1.00			42,190	1.00		
Unmarried	8617	1.50	1.39–1.62	<0.001	25,086	1.18	1.12–1.24	<0.001
Others	457	1.50	1.22–1.84	<0.001	422	1.49	1.20–1.85	<0.001
Missing	566	1.44	1.20–1.74	<0.001	743	1.27	1.07–1.50	0.005
Work status								
Employed	19,901	1.00			13,740	1.00		
Unemployed	37,341	1.29	1.23–1.35	<0.001	41,791	1.21	1.15–1.28	<0.001
Missing	6188	1.36	1.26–1.46	<0.001	12,910	1.24	1.16–1.32	<0.001
Living arrangement								
Living alone	6247	1.00			12,564	1.00		
With family members	48,700	0.63	0.58–0.69	<0.001	44,021	0.82	0.77–0.87	<0.001
Others	5820	0.66	0.59–0.73	<0.001	7952	0.88	0.81–0.94	0.001
Missing	2663	0.70	0.62–0.79	<0.001	3904	0.88	0.80–0.96	0.006
Household status								
Owned	55,534	1.00			58,987	1.00		
Rental/others	7464	1.62	1.52–1.73	<0.001	8715	1.53	1.44–1.62	<0.001
Missing	432	1.27	1.02–1.58	0.032	739	1.33	1.12–1.56	0.001

Table 2. Cont.

Characteristics	Male				Female			
	n	OR	95% CI	*p*-Value	*n*	OR	95% CI	*p*-Value
Duration of residence, years								
≤19	12,314	1.00			13,174	1.00		
20–39	19,323	0.98	0.93–1.04	0.572	19,698	0.98	0.93–1.04	0.515
40–59	17,857	0.95	0.90–1.01	0.127	28,011	0.97	0.92–1.03	0.335
60–70	10,840	1.09	1.02–1.17	0.015	5900	0.97	0.89–1.05	0.483
≥80	2332	1.18	1.05–1.33	0.007	733	1.08	0.90–1.29	0.413
Missing	764	1.26	1.06–1.49	0.009	925	1.16	0.99–1.35	0.068
Outgoing frequency								
≥4 times/week	46,463	1.00			49,337	1.00		
1–3 times/week	13,684	1.53	1.46–1.60	<0.001	15,933	1.64	1.57–1.71	<0.001
1–3 times/month	2103	2.05	1.86–2.26	<0.001	2047	2.50	2.27–2.75	<0.001
A few times/year	555	3.10	2.59–3.70	<0.001	503	3.52	2.92–4.24	<0.001
Missing	625	1.26	1.04–1.51	0.017	621	1.29	1.07–1.56	0.008
Driving habit								
No	15,170	1.00			41,030	1.00		
Yes	48,260	0.77	0.73–0.81	<0.001	27,411	0.91	0.87–0.95	<0.001
Frequency of meeting friends								
≥4 times/week	9197	1.00			12,261	1.00		
1–3 times/week	17,061	1.26	1.17–1.36	<0.001	24,962	1.43	1.34–1.52	<0.001
1–3 times/month	14,100	1.61	1.49–1.74	<0.001	15,428	1.88	1.75–2.01	<0.001
A few times/year	22,005	2.53	2.35–2.71	<0.001	14,247	2.91	2.72–3.11	<0.001
Missing	1067	1.84	1.58–2.15	<0.001	1543	1.93	1.70–2.20	<0.001

OR: Odds ratios; CI: Confidence interval.

4. Discussion

The present study confirmed the association between depression and basic demographic information as reported in previous studies: Frequency of going out and visiting friends, home ownership, length of residence in a community, and population density. For example, a significant association was found between higher education and higher income and lower risk of depression. Being married, having a family, and having a job were also associated with a lower risk of depression. Further, those who went out more frequently and had frequent interactions with friends had a lower risk of depression. Regarding the residential environment, the results suggest that owning a house and having a longer residence duration may be protective factors for the risk of depression in men. Although the association between population density and risk of depression was been consistent, the present study showed an association between higher population density and lower risk of depression [14,48].

The present analysis also suggests that older women who live near an elementary school may have a lower risk of depression than those who do not, even after controlling for basic demographic information such as frequency of going out, frequency of meeting friends, household status, duration of residence, and population density, which are reported to be associated with depression [31–39]. The ORs for the association between elementary school proximity and depression were smaller than those of basic demographic information and other data; however, the large number of participants analyzed in this study allowed us to detect the effect. We discuss several mechanisms by which the environment near an elementary school may reduce the risk of depression among older women.

4.1. High Social Capital as the Center of the Community in the Elementary School Neighborhood Environment

Social capital may be related to the association between high proximity to an elementary school and low depression. Putnam defined social capital as "features of social organization, such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit" [49]. In addition, evidence suggests that areas with higher social capital, that is, more connected people and more cooperative behavior, have lower

rates of anxiety, depression, and other psychiatric disorders. A study examining the relationship between public space and sense of community in Australian neighborhoods reported a significant association between distance to the nearest school and sense of community, with greater distance to the nearest school being linked with a lower sense of community [50]. The authors considered that participation in more neighborhood and school activities may contribute to expanding social networks, developing friendships, and a greater sense of community. In contrast, an American study reported no linear association between the distance to a school and social cohesion, which is one index of social capital [51]. The lack of association was assumed to be related to the means of transportation for getting to school. If a school has many students who commute to school by bus or private transportation, there may be fewer opportunities to increase the school's collective effects. In other words, students are more likely to walk to school in their neighborhood up to a certain threshold distance, and there is a positive relationship between social cohesion and school proximity up to that threshold. However, the relationship between social cohesion and school proximity may disappear farther away from that threshold [51]. Thus, we can speculate that the association between elementary school proximity and social capital is related to whether the school is within walking distance. More than 90% of Japanese elementary school students walk to school [52]. This study found a higher odds ratio for depression among female older adults living at a distance of more than 400 m from an elementary school, which roughly supports the findings of previous studies.

Moreover, the Ministry of Health, Labour and Welfare suggests that elementary schools can be a base for social capital because they are a venue for student activities and a place for interaction between parents and community members. Moreover, it cites the fact that the activities of community organizations are often organized within the elementary school district as a possible reason for the above factors [53]. A questionnaire survey of Japanese adults older than 65 years reported that women were less likely to go out, work, and engage in hobby activities than men. However, in contrast, women were more likely to participate in neighborhood and community association activities [54]. Given that participation in elementary school-based activities of community organizations is relevant in the mechanism by which high elementary school proximity contributes to improved social capital, sex-related differences in community activity participation may explain the association, especially for women.

4.2. The Safety of the Elementary School Neighborhood Environment

The second factor regarding high proximity to elementary schools that was associated with lower depression among older adults can be assumed to be the high safety level in the environment near elementary schools. The Cabinet Office in Japan promotes traffic safety on school routes through the cooperation of residents, schools, boards of education, municipalities, and the police, which includes community-based supervision, police patrols, and traffic restrictions [55]. In Japan, school zones are designated as critical areas for traffic safety policies to protect children from traffic accidents and are located within a 500-m radius of an elementary school on the school route. The school zone imposes various traffic restrictions, such as installing new crosswalks and curb mirrors, sidewalk widening, one-way traffic and speed restrictions, and a ban on traffic during school hours [56]. These strategies have contributed to traffic-related safety in the elementary school neighborhood environment.

Perceived neighborhood traffic-related safety was negatively related to possible depression in older adults [57,58]. Furthermore, neighborhood risk perceptions are reported to be higher in women than in men [59]. Thus, women may be more sensitive and stressed about low traffic safety in their neighborhoods. The results of this study match those of earlier studies about the high incidence of depression in women living at a greater distance from elementary schools.

4.3. Potential for Contact and Intergenerational Interaction with Children in an Elementary School Neighborhood Environment

A third factor that may contribute to less depression as elementary school proximity increases is that more frequent contact with children in the elementary school neighborhood environment may foster generativity. Erikson defined the concept of generativity as an interest in contributing to the well-being of others, especially the younger generation, and as a developmental challenge in middle age and later years [60,61]. Childbearing, parenting, and social interactions possibly foster generativity by increasing interest in the younger generation's development and well-being [60,62,63]. Furthermore, higher levels of generational interest and more frequent generational interactions, that is, greater generativity are associated with better mental health in old age [62–65]. According to the findings of a US study, intergenerational exchange was associated with improved subjective health status and psychological well-being [66]. In another study of older Japanese adults, positive intergenerational interaction was suggested to foster generativity and improve well-being in older age [61]. Previous research reported that generativity tends to be higher in women than in men [67]. Another study has shown that generativity impacts subjective well-being, with the trend being more robust in women than in men [62]. The results of this study are consistent with previous research findings, which showed that women tend to have greater generativity and better well-being.

4.4. Strengths and Limitations

The strength of this study is that it is one of the few studies that investigated the relationship between elementary school proximity and depression among older adults in a large epidemiological dataset covering both urban and rural areas. Understanding the relationship between depression in older adults and their neighborhood environment is essential for supporting community-dwelling older adults. Clarifying the health risk-preventing effects of elementary school neighborhoods, which exist in tens of thousands of locations nationwide, may have implications for city design, such as developing senior living centers near elementary schools.

Another strength of this analysis is that it uses objective data as an explanatory variable. Subjective indicators using questionnaires have often been used to analyze environmental factors; however, it has been noted that there are individual differences in the perception of subjectively measured environmental factors. The use of objective data as an indicator facilitates objective assessment and comparison of regional differences.

Nonetheless, this study has the following limitations. First, the cross-sectional design precludes the identification of a causal relationship. The second limitation is that respondents who needed long-term care and were not independent in their activities of daily living (ADLs) were excluded from this analysis. The results are only for community-dwelling older adults who can live independently before being certified for long-term care. The third limitation is that some of the residential data used in the analysis may differ from the actual address. For privacy reasons, the participant's residence point data were substituted with the latitude and longitude of the representative points of the block-level location reference information provided by the Ministry of Land, Infrastructure, and Transport. Therefore, the network distance to the nearest elementary school, which is the explanatory variable in this study, differs from the actual distance from the point of residence. However, since the average radius at the block was 258.7 m, few respondents were expected to move across this explanatory variable's 400-m category. Finally, we cannot precisely discern how elementary school proximity affects depression among older female respondents because our results did not specifically identify the factors in the elementary school neighborhood environment that prevent depression among older women. It is unknown whether it is the elementary school environment's safety and walkability or influence by direct or indirect contact with children that contributes to the abovementioned effect. A more detailed analysis is needed in the future, as clarification of the mechanisms will allow more effective and specific interventions to be implemented.

Despite the limitations described above, this study presents findings that can help create a community that prevents depression among older adults.

5. Conclusions

This study suggests that proximity to an elementary school may be a protective factor for the mental health of community-dwelling older women living independently in the community, confirming part of our hypothesis. It may encourage participation in community activities based on the elementary school and promotes interaction with children, as promoted by the age-friendly cities guide [20]. In the future, clarifying the mechanism of the protective effect of elementary school proximity on depression among older women may help examine specific interventions to prevent depression. Furthermore, examining the mechanisms underlying the gender differences in this study may help develop effective approaches for both men and women. The above research to elucidate such mechanisms could contribute to a design guide for age-friendly cities.

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Informed Consent Statement: Potential participants received written information on the purpose and significance of the JAGES study; the burden, expected risks, and possible benefits of study participation; voluntary consent and withdrawal of consent; and handling of personal information and privacy protection, and that the submission of the completed survey form would be regarded as their consent for study participation.

Data Availability Statement: Data is not suitable for public deposition due to ethical concerns. Data are from the JAGES study. Requests for data may be sent to the data management committee: dataadmin@jages.net.

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Association between social isolation and depression onset among older adults: a cross-national longitudinal study in England and Japan

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ABSTRACT

Objective Social isolation is a risk factor for depression in older age. However, little is known regarding whether its impact varies depending on country-specific cultural contexts regarding social relationships. The present study examined the association of social isolation with depression onset among older adults in England, which has taken advanced measures against social isolation, and Japan, a super-aged society with a rapidly increasing number of socially isolated people.

Design Prospective longitudinal study.

Setting We used data from two ongoing studies: the English Longitudinal Study of Ageing (ELSA) and the Japan Gerontological Evaluation Study (JAGES).

Participants Older adults aged ≥65 years without depression at baseline were followed up regarding depression onset for 2 years (2010/2011–2012/2013) for the ELSA and 2.5 years (2010/2011–2013) for the JAGES.

Primary outcome measure Depression was assessed with eight items from the Centre for Epidemiologic Studies Depression Scale for the ELSA and Geriatric Depression Scale for the JAGES. Multivariable logistic regression analysis was performed to evaluate social isolation using multiple parameters (marital status; interaction with children, relatives and friends; and social participation).

Results The data of 3331 respondents from the ELSA and 33 127 from the JAGES were analysed. Multivariable logistic regression analysis demonstrated that social isolation was significantly associated with depression onset in both countries. In the ELSA, poor interaction with children was marginally associated with depression onset, while in the JAGES, poor interaction with children and no social participation significantly affected depression onset.

Conclusions Despite variations in cultural background, social isolation was associated with depression onset in both England and Japan. Addressing social isolation to safeguard older adults' mental health must be globally prioritised.

Strengths and limitations of this study

- This is the first cross-national longitudinal study to examine the association between social isolation and depression onset in England, which has taken advanced measures against social isolation, and Japan, a super-aged society with a rapidly increasing number of socially isolated people.
- This study included a large sample of over 3300 individuals from England and 33 000 individuals from Japan aged 65 years and older.
- A limitation of this study is that we cannot make direct comparisons because of variations in cohort follow-up periods and depression measurement.
- Another limitation is the use of social support for the evaluation of social contact so as to permit the use of the same social isolation assessment scale in both countries.

INTRODUCTION

With population ageing, there is growing worldwide interest in social issues concerning older adults, including social isolation and the deterioration of physical and mental health. Defined as an objective state in where an individual has few close relationships or limited contact within a community,[1] social isolation is recognised as a social determinant of health with relevance to mortality,[2] cardiovascular diseases,[3] dementia[4] and mental health.[5 6] Social isolation is a major risk factor for mental health problems in older age. Several systematic reviews have demonstrated that social isolation is associated with depressive symptoms,[5 6] which, in turn, are correlated with unhealthy behaviours and reduced access to material resources.[7] Depression, common in later life, is related to adverse health outcomes such as poor quality of life[8] and functional disability.[9] With the high current global burden of depression expected to increase further by 2030,[10] addressing social isolation is an important gerontological issue for protecting mental health among older adults.

The impacts of social isolation on health may vary by country; this could be the result of differences in the social environments related to social networks within and outside the family. A recent study of older adults in England and Japan showed that social isolation is a common risk factor for mortality in both countries, with a greater impact observed in England; the results are discussed in terms of possible differences between societies that are highly connected and those that are not.[11] In the UK, in recognition of the impact of social isolation on health and economic loss, the position of 'Minister of Loneliness' was established in 2018, and the country is taking a progressive approach to the elimination of social isolation.[12] In contrast, Japan, now a super-aged society (more than 21% of the population aged 65 or above),[13] is experiencing a rapidly increasing trend in the number of never-married persons and weakening community and neighbourhood relations,[14] leading to a rise in the number of socially isolated individuals.[15] In Japan, the proportion of people who rarely or never spend time with those close to them has been reported to be the highest among Organisation for Economic Co-operation and Development countries. In particular, this figure is much higher than in the UK, which has made advances in tackling social isolation (Japan=15.3%, UK=5.0%).[16] Owing to differences in social structures and the contexts surrounding social isolation, the impact of social isolation on depression is expected to vary across countries.

Furthermore, the health effects of social isolation may differ depending on the cultural context of social relationships. In East Asian countries, including Japan, there is a familial norm based on the traditional culture of filial piety,[17] which is often contrasted with individualism in Western countries.[18 19] Based on this cultural background, Japanese social support networks may be kinship centred, which may be narrower than the types of social networks prevalent in other countries.[20] However, there is a lack of consensus on the health effects of social relationships based on these cultural differences. A previous cross-national study showed that among English men, friendship-based social relationships had a significant impact on longevity, whereas among Japanese men, this impact was associated with family-based social relationships.[21] In contrast, a study of older adults in the USA and Japan demonstrated that while relationships with children were associated with a low level of depression only in Japan, the presence of spouses was important in both countries, but more so in the USA.[22] Another comparative study among adults suggested that social contact with friends benefited women's mental health in the UK but not in Japan.[23] Thus, the family-oriented nature of East Asian societies does not automatically imply the health importance of family-based relationships, and the roles of individual components of social isolation (family, friends and others) in the mental health of older adults in each country remain controversial.

As the association between social isolation and depression is often described as bidirectional,[24] longitudinal studies are needed to address temporality. However, previous cross-national comparative studies have employed only cross-sectional designs.[22 23] Therefore, using longitudinal data from both countries, the present study aims to investigate the association of social isolation with depression onset in England, which has taken advanced measures against social isolation, and Japan, a super-aged society with a rapidly increasing number of socially isolated people.

METHODS

Sample

This longitudinal study was conducted using data from two ongoing prospective cohort studies: the English Longitudinal Study of Ageing (ELSA) and the Japan Gerontological Evaluation Study (JAGES). The ELSA targets independent-living older adults aged ≥50, while JAGES participants are community-dwelling individuals aged ≥65 who are ineligible for long-term healthcare insurance benefits.[25] Details of the ELSA and JAGES can be found elsewhere.[26 27] For the present analysis, we used the two waves of data that most closely corresponded with the timing of our study: wave 5 (2010/2011) to wave 6 (2012/2013) for the ELSA, and wave 1 (2010/2011) to wave 2 (2013) for the JAGES. We harmonised the data by including older adults aged ≥65, independent in activities of daily living, and without self-reported dementia. For analysis, respondents who scored above the cut-off point for depression on each measure in the respective cohort at baseline were excluded and we followed up the onset of depression for 2 years for the ELSA and 2.5 years for the JAGES.

Depression

Based on a previous cross-national study,[28] depressive symptoms were measured both at baseline and follow-up using eight items from the Centre for Epidemiologic Studies Depression Scale (CES-D 8) in the ELSA[29] and the Geriatric Depression Scale (GDS-15) in the JAGES.[30] To identify possible depressive cases, the CES-D 8 cut-off was ≥4 while that for the GDS-15 was ≥5.[31 32] As previously mentioned, respondents with depression at baseline were excluded and we observed the onset of depression during the follow-up.

Social isolation

Social isolation levels were assessed using a modified version of the Social Isolation Index (SII).[33–35] The index was computed with respondents given a point if they: (1) were unmarried or living alone, (2) had poor interaction with children (did not live with their children or had no one to provide emotional or instrumental social support), (3) had poor interaction with relatives (did not have immediate family members providing emotional or instrumental social support), (4) had poor interaction with friends (less than monthly contact or no friends who could provide emotional or instrumental social support)

and (5) had no social participation (no participation in any social or religious groups). The total possible score ranged from 0 to 5, with higher scores indicating greater social isolation. The participants were categorised into the following five groups based on their scores: 0, 1, 2, 3 and 4–5 points. We used the total score and the scores of the five subcomponents as predictive variables.

Covariates

The covariates included age, gender, educational attainment, household equivalised income, present illness, self-rated health, smoking and drinking. Age was categorised as 65–69, 70–74, 75–79, 80–84 and ≥85. Based on the ages of respondents who had completed formal education, the age of final educational attainment was categorised as ≤15 years, 16–18 years and ≥19 years. Household equivalised income was classified into quintiles. Present illness was classified as 'yes' or 'no' for cancer, heart disease and stroke. Self-rated health was dichotomised as 'poor' and 'good'. Smoking and drinking were dichotomised as 'never/past' and 'current'.

Statistical analysis

We analysed the ELSA and JAGES data separately because of differences in research design, especially sampling approaches. A longitudinal weight was applied to account for survey non-response for the ELSA but not the JAGES as its design does not allow it. First, we calculated descriptive statistics. Second, we conducted a multivariable logistic regression analysis to examine the association between SII score and depression onset and obtained ORs and 95% CIs for depression onset. Model 1 was not adjusted for covariates while Model 2 was adjusted for all covariates. Additionally, we analysed the association between SII subcomponents and depression onset, adjusted for all covariates.

To mitigate potential biases resulting from missing information, we used the multiple imputation approach under the missing at random assumption. We generated 20 imputed datasets for the final analysis, which excluded those who met the exclusion criteria and did not respond to the follow-up surveys, using the multiple imputation by chained equations procedure and pooled the results using Rubin's rule.[36]

The significance level was set at P<0.05. We used R (V.3.5.2 for Windows) for all statistical analyses.

Patient and public involvement

No patients were involved in the development of the research question, study design or data interpretation.

RESULTS

A total of 3331 ELSA respondents and 33 127 JAGES respondents were included in the final analysis. Their baseline characteristics are presented in table 1. The mean age (SD) was 73.6 (6.9) years for the ELSA and 72.4 (5.4) years for the JAGES. Regarding SII scores, the ELSA had the largest number of respondents with 0 and 1 points, while the JAGES had the largest number with 2 and 3 points. In the ELSA, respondents who were older, male, less educated, had a lower income, had heart disease, had poor self-rated health, smoked, consumed little alcohol and had higher baseline depressive symptom scores and higher SII scores. A similar trend was observed in the JAGES, but here, those who consumed more alcohol had higher SII scores.

Table 2 presents the description of social isolation and depression onset. At follow-up, 201 (6.0%) ELSA respondents and 4456 (13.5%) JAGES respondents exhibited depression onset. In both studies, higher SII scores were associated with an increased risk of depression onset. Regarding SII subcomponents, ELSA respondents who were unmarried or living alone were more likely to have depression, while this was the case with JAGES respondents with no social participation.

Table 3 depicts the association between SII scores and depression onset. Multivariable analysis showed that higher SII scores were associated with a higher risk of depression onset in both studies after adjusting for all covariates. In the ELSA, the OR of depression onset was significantly higher from a score ≥1 point (OR [95% CI] compared with zero points, one: 1.68 [1.02 to 2.75], two: 1.77 [1.03 to 3.05], three: 2.64 [1.37 to 5.12], ≥four: 4.01 [1.43 to 11.22], P for trend=0.015). In the JAGES, as SII scores increased, the OR of depression onset gradually increased, reaching significance at ≥three points (OR [95% CI] compared with zero points, one: 1.10 [0.89 to 1.35], two: 1.15 [0.94 to 1.40], three: 1.28 [1.04 to 1.56], ≥four: 1.48 [1.18 to 1.85], P for trend <0.001). These results showed almost the same tendency as the complete case analysis without multiple imputation (online supplemental table 1).

Table 4 presents the associations of SII subcomponents with depression onset. In the ELSA, subcomponents were not significant, although poor interaction with children was marginally significant (OR [95% CI]) with 'none' as the reference; unmarried or living alone: 1.13 [0.80 to 1.60], poor interaction with children: 1.55 [1.00 to 2.41], poor interaction with relatives: 1.24 [0.79 to 1.94], poor interaction with friends: 1.15 [0.77 to 1.71], no social participation: 1.22 [0.80 to 1.87]). In the JAGES, poor interaction with children and no social participation were significantly associated with depression onset after adjusting for all covariates (OR [95% CI], with 'none' as the reference; unmarried or living alone: 1.11 [1.00 to 1.24], poor interaction with children: 1.09 [1.01 to 1.19], poor interaction with relatives: 1.04 [0.96 to 1.12], poor interaction with friends: 1.03 [0.95 to 1.11], no social participation: 1.28 [1.17 to 1.40]). These results were similar to those obtained from the complete case analysis (online supplemental table 2).

DISCUSSION

To the best of our knowledge, this is the first cross-national longitudinal study of the association of social isolation with depression among older English and Japanese adults. Social

Table 1 Respondents' baseline characteristics

	ELSA*					JAGES				
	Social Isolation Index score†					Social Isolation Index score†				
	0	1	2	3	≥4	0	1	2	3	≥4
	n=905 (27.2%)	n=1049 (31.5%)	n=596 (17.9%)	n=216 (6.5%)	n=49 (1.5%)	n=1402 (4.2%)	n=5981 (18.0%)	n=9723 (29.4%)	n=8735 (26.4%)	n=2176 (6.6%)
Age (years), (%)										
65–69	41.0	36.4	29.9	27.6	28.3	38.6	40.5	38.0	37.0	35.8
70–74	26.1	28.3	28.8	29.3	23.6	32.1	32.5	31.6	31.0	30.4
75–79	20.9	17.5	19.3	15.8	20.4	19.2	18.3	19.5	20.3	21.9
80–84	9.1	12.2	12.5	14.5	15.5	8.3	6.7	8.3	9.0	8.8
≥85	2.8	5.7	9.5	12.8	12.2	1.9	2.0	2.6	2.7	3.1
Gender, (%)										
Men	50.0	46.1	45.3	51.9	65.8	27.2	35.1	47.0	64.4	66.1
Women	50.0	53.9	54.7	48.1	34.2	72.8	64.9	53.0	35.6	33.9
Educational attainment (years), (%)										
≤15	44.1	51.3	52.3	60.9	69.6	42.9	38.1	37.9	38.7	48.6
16–18	35.0	33.8	34.6	27.5	14.1	40.9	40.8	39.3	36.8	31.1
≥19	17.8	12.5	11.0	10.3	14.0	15.7	20.4	21.8	23.3	18.5
Missing	3.2	2.4	2.1	1.3	2.3	0.5	0.7	0.9	1.2	1.8
Household equivalised income, (%)										
First quintile (lowest)	11.4	18.3	23.2	31.2	14.4	7.4	10.9	13.9	15.6	21.3
Second quintile	21.5	23.7	26.1	24.1	29.6	13.2	13.5	15.0	15.5	16.4
Third quintile	20.9	21.8	18.9	19.5	27.1	22.5	30.6	30.3	30.6	28.0
Fourth quintile	21.9	19.9	18.1	16.5	16.6	14.3	13.6	12.7	11.3	9.5
Fifth quintile (highest)	22.7	15.0	12.7	8.3	12.4	31.5	22.5	19.2	16.8	12.9
Missing	1.5	1.3	0.9	0.4	0.0	11.1	8.9	8.9	10.2	11.9
Cancer, (%)										
No	96.5	95.8	97.1	97.5	96.5	91.0	91.2	90.8	90.1	89.7
Yes	3.4	4.2	2.9	2.5	3.5	3.2	3.1	3.1	3.4	3.7
Missing	0.1	0.0	0.0	0.0	0.0	5.8	5.7	6.1	6.5	6.6
Heart disease, (%)										
No	90.7	86.9	88.4	88.3	77.3	91.0	91.2	90.8	90.1	89.7
Yes	9.3	13.0	11.6	11.7	22.7	3.2	3.1	3.1	3.4	3.7
Missing	0.0	0.1	0.0	0.0	0.0	5.8	5.7	6.1	6.5	6.6
Stroke, (%)										
No	96.3	96.1	97	94.4	96.6	93.3	93.6	93.1	92.5	92.2
Yes	3.7	3.8	3.0	5.6	3.4	0.9	0.8	0.8	1.0	1.2
Missing	0	0.1	0.0	0.0	0.0	5.8	5.7	6.1	6.5	6.6
Self-rated health, (%)										
Good	86.4	79.9	78.8	75.4	71.3	92.0	91.7	90.6	90.2	87.2
Poor	13.6	20.1	21.2	24.6	28.7	7.2	7.7	8.6	9.0	12.2
Missing	0.0	0.0	0.0	0.0	0.0	0.8	0.5	0.8	0.8	0.6
Smoking, (%)										
Never/past	95.5	93.1	89.8	82.9	89.4	86.4	86.1	82.9	81.5	78.4
Current	4.5	6.9	10.2	17.1	10.6	6.4	7.4	9.5	11.3	14.2

Continued

Table 1 Continued

	ELSA*					JAGES				
	Social Isolation Index score†					Social Isolation Index score†				
	0	1	2	3	≥4	0	1	2	3	≥4
	n=905 (27.2%)	n=1049 (31.5%)	n=596 (17.9%)	n=216 (6.5%)	n=49 (1.5%)	n=1402 (4.2%)	n=5981 (18.0%)	n=9723 (29.4%)	n=8735 (26.4%)	n=2176 (6.6%)
Missing	0.0	0.0	0.0	0.0	0.0	7.1	6.5	7.5	7.2	7.3
Drinking, (%)										
Never/past	7.5	11.8	14.9	25.8	17.3	65.0	60.0	56.5	50.4	55.0
Current	91.3	87.0	82.9	72.6	73.6	30.2	35.7	38.6	44.7	40.4
Missing	1.3	1.2	2.2	1.6	9.2	4.8	4.3	4.9	4.9	4.6
CES-D 8 score at baseline, (%)										
0	57.2	52.0	45.5	42.2	54.0					
1	27.3	26.2	28.6	31.8	25.5					
2	9.8	13.8	17.1	11.9	15.1					
3	5.7	8.0	8.8	14.2	5.4					
GDS score at baseline, (%)										
0						20.5	30.4	29.0	26.4	24.3
1						25.5	28.4	28.6	26.9	27.0
2						22.5	20.0	19.8	21.5	21.1
3						17.5	13.1	13.5	14.7	15.9
4						14.1	8.1	9.1	10.5	11.7

*ELSA data after sampling weight.
†Missing data: ELSA, n=516; JAGES, n=5110.
CES-D 8, eight items from the Centre for Epidemiologic Studies Depression Scale; ELSA, English Longitudinal Study of Ageing; GDS, Geriatric Depression Scale; JAGES, Japan Gerontological Evaluation Study.

isolation was significantly associated with depression onset in both countries. Our results support previous longitudinal findings on social relationships and mental health among older adults in England[37] and Japan.[38] Using data frames that were similar with regard to assessment and covariates, we demonstrated that social isolation is a common risk factor for depression in England and Japan, despite country-specific cultural differences regarding social relationships. Thus, our results suggest that to safeguard the mental health of older adults, addressing social isolation is a global need.

The association between social isolation and depression was somewhat stronger in England than in Japan. These results are similar to a previous report concerning mortality among older adults in England and Japan.[11] Although we cannot make direct comparisons due to variations in cohort follow-up periods and depression measurement, there are several possible reasons for this pattern of findings. The impact of social factors could differ depending on the group and society to which one belongs. This is best understood in the context of the concept of relative deprivation.[39] In other words, higher levels of relative social isolation may induce greater psychological stress. A previous study showed that rich community ties and cohesion were protective factors for health but could have a negative effect on those who were not socially involved.[40] Being isolated in a connected society such as the UK may represent a more severe condition, with a stronger negative impact on mental health.

Our results revealed that poor interaction with children was significant with regard to depression onset in Japan. In England, while the association was marginal, of the components of social isolation, poor interaction with children had the greatest effect. The lack of interaction with children could have an adverse effect on the mental health of older adults in both countries. Previous studies in England[41] and Japan[22] have reported that social support from children can contribute to alleviating depression, and our results point in the same direction. Older adults without children can be considered a vulnerable group, because adult children, in particular, are often the main source of positive social support for older parents.[42] Older parents have certain expectations with regard to receiving support from their children, and situations wherein these expectations are not met may lead to depressive mood.[43] However, a previous study reported no association between the presence of children and depression among older adults in the USA.[22] Owing to strong spousal relationships in the USA, the effect of the presence of children might be relatively small. Thus, our study confirmed the adverse effects of poor interaction with children common to England and Japan, but international generalisability can only be established based on further research considering

Table 2 Description of social isolation status and depression onset

	ELSA*		JAGES	
	CES-D 8 score at follow-up		GDS score at follow-up	
	<4	≥4	<5	≥5
	n=3130 (94.0%)	n=201 (6.0%)	n=28 671 (86.5%)	n=4456 (13.5%)
Social Isolation Index score, (%)				
0	27.5	13.5	4.4	3.0
1	31.2	29.3	18.6	14.3
2	17.9	18.9	29.8	26.3
3	6.5	10.1	26.2	27.5
≥4	1.5	2.9	6.1	9.3
Missing	15.4	25.3	14.8	19.7
Social Isolation Index sub-components, (%)				
Unmarried or living alone	71.9	58.5	88.3	85.2
No				
Yes	28.1	41.5	10.2	12.7
Missing	0.0	0.0	1.4	2.1
Poor interaction with children	81.8	73.4	26.6	25.0
No				
Yes	12.5	14.7	71.7	72.9
Missing	5.7	11.8	1.7	2.1
Poor interaction with relatives	76.3	68.1	41.1	38.7
No				
Yes	17.3	18.6	54.4	56.0
Missing	6.4	13.4	4.5	5.4
Poor interaction with friends	72.2	66.0	37.1	31.2
No				
Yes	18.4	21.6	58.2	63.8
Missing	9.4	12.4	4.6	5.0
No social participation	61.7	46.3	75.0	63.9
No				
Yes	28.4	32.5	13.0	20.0
Missing	10.0	21.2	11.7	16.1

*ELSA data after sampling weight.
CES-D 8, eight items from the Centre for Epidemiologic Studies Depression Scale; ELSA, English Longitudinal Study of Ageing; GDS, Geriatric Depression Scale; JAGES, Japan Gerontological Evaluation Study.

the cultural background of family relationships in individual countries.

Although traditionally Japan is a country in which adult children are expected to demonstrate reciprocity with their parents based on the strong family and kinship-based cultural background,[44] in this study, the effect of interaction with children on depression was relatively modest. In recent years, with trends such as adult children commonly living apart from their parents after marriage[45] and the development of public long-term care services for the ageing population,[46] Japan's family system has become less traditional. Therefore, interaction with children may not be as essential to the health of older adults as before. However, despite these cultural transitions, we believe that interaction with children has some value with regard to preventing depression in old age in Japan.

Social participation was a strong protective factor for depression onset in Japan, whereas there was no association in England, although the OR was somewhat greater. Several previous studies have reported that social participation helps prevent depression onset.[37 47–49] Our results pertaining to Japan support these reports. However, the protective effects of social participation on mental health vary depending on the type of organisation with which an individual is involved,[48]

Table 3 Association between social isolation and depression onset: multivariable logistic regression analysis

	ELSA		JAGES	
	Crude OR (95% CI)	Adjusted OR (95% CI)	Crude OR (95% CI)	Adjusted OR (95% CI)
Social Isolation Index score				
0	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
1	1.92** (1.19 to 3.10)	1.68* (1.02 to 2.75)	1.14 (0.94 to 1.39)	1.10 (0.89 to 1.35)
2	2.15** (1.28 to 3.62)	1.77* (1.03 to 3.05)	1.32** (1.09 to 1.60)	1.15 (0.94 to 1.40)
3	3.19*** (1.73 to 5.90)	2.64** (1.37 to 5.12)	1.57*** (1.30 to 1.90)	1.28* (1.04 to 1.56)
≥4	3.85** (1.46 to 10.18)	4.01** (1.43 to 11.22)	2.26*** (1.83 to 2.79)	1.48*** (1.18 to 1.85)
	P for trend <0.001	P for trend=0.015	P for trend <0.001	P for trend <0.001

Adjusted for age, gender, educational attainment, household equivalised income, present illness (cancer, heart disease, and stroke), self-rated health, smoking, drinking, and depression score at baseline (eight items from the Centre for Epidemiologic Studies Depression Scale for the ELSA and Geriatric Depression Scale for the JAGES).
*P<0.05; **P<0.01; ***P<0.001.
ELSA, English Longitudinal Study of Ageing; JAGES, Japan Gerontological Evaluation Study.

the individual's attitude towards participation,[48] and the duration[37] and frequency[49] of participation. Regarding the present study, in the English context, the role of social participation in depression prevention might have been unidentifiable due to differences in the effects of these participation contexts. We took into account only social participation, without delving into specific types. Thus, the context of effective social participation, such as type, duration, and role in the organisation in both countries, requires further investigation. Despite these challenges, our findings suggest that in Japan, social isolation prevention measures based on the promotion of social participation could be beneficial for safeguarding the mental health of older adults.

This study has several strengths. First, it is the first cross-national population-level investigation of the association of social isolation with depression onset using a unified data frame. Second, by using two longitudinal datasets, we were able to examine the prospective association between social isolation and depression. Third, the use of large-scale data allowed us to detect the effects of relatively rare situations of severe social isolation.

However, certain limitations cannot be ignored. First, the measurement of depression in the two cohorts was not the same. Therefore, we could not directly compare depression onset in the two countries. However, these measurements were also used in a previous cross-national comparison study in England and Japan,[28] and we were able to examine the association between social isolation and depression onset in both countries using the same data frame. Second, we used social support for the assessment of social contact for some items in order to be able to use the same SII. Therefore, cultural differences in expectations regarding the receipt of social support in both countries might have caused information biases. For instance, expectations regarding social support from relatives could originally have been higher in Japan,[44] leading to overestimation of social isolation levels. Third, regarding the items of the SII, the questions and their response options in the ELSA and JAGES were not exactly the same, nor were they strictly authorised through procedures such as reverse translation and confirming reliability and validity. However, we believe it is certainly meaningful to evaluate social isolation using the same framework. Finally,

Table 4 Association between subcomponents of social isolation and depression onset: multivariable logistic regression analysis

	ELSA	JAGES
	Adjusted OR (95% CI)	Adjusted OR (95% CI)
Social Isolation Index subcomponents (reference: none)		
Unmarried or living alone	1.13 (0.80 to 1.60)	1.11† (1.00 to 1.24)
Poor interaction with children	1.55† (1.00 to 2.41)	1.09* (1.01 to 1.19)
Poor interaction with relatives	1.24 (0.79 to 1.94)	1.04 (0.96 to 1.12)
Poor interaction with friends	1.15 (0.77 to 1.71)	1.03 (0.95 to 1.11)
No social participation	1.22 (0.80 to 1.87)	1.28*** (1.17 to 1.40)

Adjusted for age, gender, educational attainment, equivalent income, present illness (cancer, heart disease and stroke), self-rated health, smoking, drinking and depression score at baseline (eight items from the Centre for Epidemiologic Studies Depression Scale for the ELSA and Geriatric Depression Scale for the JAGES).
*P<0.05; ***P<0.001;†P<0.1.
ELSA, English Longitudinal Study of Ageing; JAGES, Japan Gerontological Evaluation Study.

there were differences in study design in the data from the two cohorts, such as sampling method and follow-up period. We, therefore, made efforts to harmonise the data: those aged ≤64, with dementia, and dependent in activities of daily living were excluded from the analysis. Moreover, the ELSA presents nationally representative population data, while the JAGES does not. However, the JAGES sample is representative of areas from a nationwide ageing study in which approximately one-fifth of all prefectures (9 out of 47) were enrolled. Even so, unlike the ELSA, analysis in the JAGES does not use sampling weights, which may lead to selection bias.

CONCLUSION

We examined the association between social isolation and depression onset among older adults in England and Japan, who experience different cultural contexts regarding social relationships, and found a significant association in both countries; we also observed that in England, poor interaction with children was marginally associated, and in Japan, poor interaction and lack of social participation were significantly associated with depression. Tackling social isolation must be prioritised to safeguard the mental health of older adults worldwide. Particularly in Japan, the promotion of interaction with children and social participation could be key factors in addressing social isolation.

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Competing interests None declared.

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ACCEPTED MANUSCRIPT

Causal Inference in Studying the Long-term Health Effects of Disasters: Challenges and Potential Solutions

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Abstract

Two frequently encountered but underrecognized challenges for causal inference in studying the long-term health effects of disasters among survivors include: (a) time-varying effects of disasters on a time-to-event outcome and (b) selection bias due to selective attrition. We review approaches to overcome these challenges and show application of the approaches to a real-world longitudinal data of older adults who were directly impacted by the 2011 earthquake and tsunami (n=4,857). To illustrate the problem of time-varying effects of disasters, we examined the association between degree of damage due to the tsunami and all-cause mortality. We compared results from Cox regression assuming proportional hazards versus adjusted parametric survival curves allowing for time-varying hazard ratios. To illustrate the problem of selection bias, we examined the association between proximity to the coast (a proxy for housing damage from the tsunami) and depressive symptoms. We corrected for selection bias due to attrition in the two post-disaster follow-up surveys (conducted in 2013 and 2016) using multivariable adjustment, inverse probability censoring weighting, and survivor average causal effect estimation. Our results demonstrate that the analytic approaches ignoring time-varying effects on mortality and selection bias due to selective attrition may underestimate the long-term health effects of disasters.

Keywords: causal inference, disaster, inverse probability weighting, selection bias, standardization, survival analysis, survivor average causal effect
Topic: disasters, survivors, epidemiologic causality, tsunamis, experimental attrition
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Community-Level Sports Group Participation and Health Behaviors Among Older Non-Participants in a Sports Group: A Multilevel Cross-Sectional Study

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Abstract: This study validates the relationship between community-level sports group participation and the frequency of leaving the house and transtheoretical model stages of behavior change for exercise among older individuals who did not participate in a sports group. We used cross-sectional data from the 2016 Japan Gerontological Evaluation Study. The proportion of sports group participants at the community level was calculated using the data from 157,233 older individuals living in 1000 communities. We conducted a multilevel regression analysis to examine the relationship between the proportion of sports group participants and the frequency of leaving the house (1 day/week or less) and the transtheoretical model stages of behavior change for exercise. A statistically significant relationship was observed between a high prevalence of sports group participation and lower risk of homeboundness (odds ratio: 0.94) and high transtheoretical model stages (partial regression coefficient: 0.06) as estimated by 10 percentage points of participation proportion. Older individuals, even those not participating in a sports group, living in a community with a high prevalence of sports group participation are less likely to be homebound; they are highly interested and have numerous opportunities to engage in exercise.

Keywords: multilevel analysis; social capital; contextual effect; housebound; exercise epidemiology

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1. Introduction

Older individuals engaging in sports and exercises while participating in groups are at lower risk of functional disability, depressive symptoms, and falls than those engaging in sports and exercises alone without participating in such groups [1–3]. The suspected mechanisms underlying health outcomes that are more likely to be obtained through sports group participation rather than individual exercise involve the benefits of physical (e.g., inducing good adherence and long duration of exercise) [4–6], psychological (e.g., enjoyment, enhanced self-esteem, and decreased stress) [4,7], and social (e.g., receiving social support, social capital, and social influence) factors [4,7,8]. Furthermore, community-level sports group participation had a preventive effect on depressive symptoms [9] and cognitive impairment [10] in older individuals. This result indicated that regardless of participation in a sports group, older individuals living in communities with a high prevalence of sports group participation were less likely to present with depressive symptoms and develop cognitive impairment than those living in a community with a low prevalence of participation. However, the reason why older individuals who do not participate in community sports groups remain healthy is not fully elucidated.

Civic participation, such as sports group participation, is a component of social capital [11]. One of the pathways between community-level social capital and individual-level health outcomes is social contagion, referring to the notion that behaviors spread more quickly through a tightly knit social network [12]. The social contagion extends to older individuals who may be encouraged by sports group participants to increase their interest and prepare to engage in sports and exercise activities. As a result, even if individuals do not join a sports group, several older individuals may frequently go out, have an interest in engaging in exercise and sports, and acquire those habits. A decrease in the frequency of going out and being homebound are known markers of complex comorbidities and vulnerability, and a specific population who is at risk possesses these characteristics [13]. Furthermore, in reference to the transtheoretical model stages of behavior change (i.e., precontemplation, contemplation, preparation, action, and maintenance stages), staying at a higher stage is considered a healthy lifestyle [14]. From the public health and health promotion perspectives, establishing an effective approach to progress the stage of behavior change is required [15].

This multilevel cross-sectional study examines whether the frequency of leaving the house was maintained and the transtheoretical model stages of behavior change for exercise were high among older individuals, even those who do not participate in the sports group, living in a community with numerous sports group participants.

2. Materials and Methods

2.1. Study Design and Participants

We used cross-sectional data from the Japan Gerontological Evaluation Study (JAGES), which is an ongoing cohort study exploring social, environmental, and behavioral factors correlated with health loss, particularly functional decline or cognitive impairment, among individuals aged 65 years or older [16]. We mailed a set of questionnaires to 279,661 community-dwelling individuals between October 2016 and January 2017, and these individuals were randomly selected from 39 municipalities, including metropolitan, urban and semi-urban, and rural communities, in 18 prefectures from as far north as Hokkaido (i.e., the northernmost prefecture) and as far south as Kyushu (i.e., the southernmost region) in Japan. The exclusion criteria were as follows: individuals receiving support and long-term care certification under the Japanese long-term care insurance system [17]; those having limitations in performing activities of daily living, which is defined as inability to walk, bathe, or use the toilet without assistance; and those living in communities with $\leq$30 respondents. One community was defined primarily by the school district. In the procedure of generating community-level variables of sports group participation, respondents who did not answer the extent of sports group participation were considered as "non-participants" in a sports group regardless of the status of individual exercise, and aggregated individual-level sports group participation according to community area was considered a community-level independent variable. With regard to the procedure of conducting the main statistical analysis, we further excluded respondents with incomplete information on sex, extent of sports group participation, or each outcome variable or those who participated in a sports group 1 day/month or more.

2.2. Measurements

2.2.1. Frequency of Leaving the House

The participants were assessed for the frequency of leaving the house (including to one's garden, immediate neighborhood, shopping complex, and hospital). The choices for the answers were as follows: $\geq$4 days/week, 2–3 days/week, 1 day/week, 1–3 days/month, a few times/year, and zero. We defined going out 1 day/week or less as mostly homebound [13,18], and this was previously associated with a higher mortality risk among community-dwelling older individuals [18].

2.2.2. Transtheoretical Model Stages of Behavior Change for Exercise

The transtheoretical model stages of behavior change assess an individual's readiness to act on a healthier behavior [14]. In this study, the participants were asked the question, "which of the following best describes your current lifestyle?" Here, regular exercise is defined as performing exercise once a week or more for at least 20 min per session. The choices for the answers were as follows: (1) not engaging in regular exercise and the lack of intention to start exercising in the future, (2) have not started exercising yet but committed to taking action within 6 months, (3) performing minimal exercises but not consistent, (4) exercising consistently for less than 6 months, and (5) exercising consistently for 6 months or more. We referred to the question item that was validated for Japanese adults [19]; however, we revised the frequency of regular exercise from twice a week to once a week, considering that the participants of this study were older individuals. The series had five stages, that is, precontemplation, contemplation, preparation, action, and maintenance, and an individual will go through these stages in adopting a healthy behavior or quitting an unhealthy behavior [14,20,21].

2.2.3. Community-Level Sports Group Participation

The participants were assessed for the frequency of sports group participation. The choices for the answers were as follows: ≥4 days/week, 2–3 days/week, 1 day/week, 1–3 days/month, a few times/year, and zero. We defined participating 1 day/month or more as participation in a sports group [9,22], and aggregated individual-level sports group participation according to the community area defined primarily by the school district was considered a community-level independent variable. A study has indicated a strong correlation between the proportion of older individuals with poor self-rated health and depressive symptoms living in areas with community-level sports group participation once a month or more ($r = -0.233$ and -0.355, respectively) compared with community-level sports group participation once a week or more ($r = -0.210$ and -0.314, respectively) [22].

2.2.4. Covariates

We evaluated confounding variables between community-level sports group participation and individual-level health status [9]. Data on basic demographic characteristics, including sex and age, were collected. The participants were divided into the following age groups: 65–69, 70–74, 75–79, 80–84, and ≥85 year groups. Then, they were queried on their household members and categorized as living with others or living alone. Drinking and smoking status (none, past, or current) and education (<10, 10–12, or ≥13 years) were classified according to each answer. Annual equivalent income was calculated by dividing the household income by the square root of the number of household members and categorized into the following three groups: JPY <2,000,000; JPY 2,000,000–3,999,999; and JPY ≥4,000,000. To obtain information about disease status in treatment, the participants were asked if they were currently receiving any medical treatment or had secondary diseases; the answer was either yes or no. If the participants did not respond to the individual-level covariates, corresponding observations were assigned to the missing categories. As community-level covariates, population density per km^2 of inhabitable area and mean annual household income for each community area were calculated and categorized into the following quartile categories: ≥10,000; 7000–9999; 2500–6999; and <2500 individuals per km^2 and JPY ≥2,713,000; JPY 2,468,000–2,712,999; JPY 2,250,010–2,467,999; and JPY <2,250,010, respectively.

2.3. Statistical Analysis

This analysis was conducted from January 2019 to March 2019. The multilevel analysis framework assumes that the health outcome of an individual partly depends on the community in which an individual lives. Multilevel models estimate the variations in outcome between communities (random effects) and the effects of community-level variables while adjusting for individual- and community-level characteristics (fixed effects).

Multilevel logistic regression analysis was conducted to calculate the odds ratio (OR) and 95% confidence interval (CI) for being mostly homebound, and multilevel mixed-effects linear regression analysis was performed to calculate the partial regression coefficient (*B*) and 95% CI for the transtheoretical model stages of behavior change for exercise. The OR and *B* of community-level sports group participation was estimated as a 10-percentage point change in aggregated sports group participation. The following three models of analysis were used: the null model, crude model including community-level sports group participation, and fully adjusted model (the crude model + all covariates). We calculated the proportional changes in the variance of the crude and fully adjusted models to the null model to estimate how much the community-level variances of the frequency of leaving the house and transtheoretical model stages of change were explained by the exposure and covariates. Furthermore, we conducted a subgroup analysis by age groups (65–69, 70–79, and ≥80 years) to investigate whether the relationships were consistent or not. Analyses were performed using Stata/MP 14.2 (Stata Corp., College Station, TX, USA).

3. Results

Figure 1 shows the flow of the participants in this study. We received responses from 196,438 individuals, with a response rate of 70.2%. We excluded 38,707 respondents who received support and long-term care certification or who have limitations in performing activities of daily living and 498 respondents who lived in communities with ≤30 respondents. Thus, 157,233 respondents (mean and standard deviation for age: 73.8 ± 6.0 years) living in 1000 communities. They were considered analytic participants for generating community-level variables of sports group participation and mean annual household income. Furthermore, we excluded respondents with incomplete information on sex (n = 23) or extent of sports group participation (n = 25,641) or those who participated in a sports group 1 day/month or more (n = 40,879). Individuals with missing information on each outcome were excluded as well. Finally, 89,847 participants were considered analytic participants for the frequency of leaving the house analysis. With regard to the transtheoretical model stage analysis, the analytical sample comprised 10,487 participants because the question item was distributed to one-eighth of the participants who were randomly allocated.

Table 1 shows the demographic characteristics of the participants according to each analysis. Among the 89,847 analytic participants of the frequency of leaving the house analysis, 7364 (8.2%) reported going out 1 day/week or less and were categorized as mostly homebound. Among the 10,487 analytic participants for the transtheoretical model stage analysis, approximately 40% (n = 4356) were at the precontemplation stage, whereas 20% (n = 2260) were at the action or maintenance stage. Table 2 shows the descriptive statistics for the community-level variables. The mean proportion of sports group participants was 26.7% (standard deviation: 7.6%; range: 2.0–50.5%).

Table 3 and Table S1 show the results of the multilevel regression analyses. According to the analysis of the frequency of leaving the house, regardless of models including covariates, a higher prevalence of sports group participation is statistically significantly associated with a lower risk of homeboundness (OR: 0.94; 95% CI: 0.89–0.996 in the adjusted model), as estimated by 10-percentage points of participation proportion. The community-level variance decreased by 22.5% with the addition of the proportion of sports group participants and 36.3% with the addition of all covariates to the null model. In addition, community-level sports group participation was positively associated with the transtheoretical model stages of behavior change for exercise (*B*: 0.06; 95% CI: 0.01–0.12 in the adjusted model), and the community-level variance decreased by 23.1% and 38.5%, respectively. Table S2 shows the subgroup analysis by age groups. The direction of relationships was consistent among age groups although the 95% CIs were widened due to the smaller sample size.

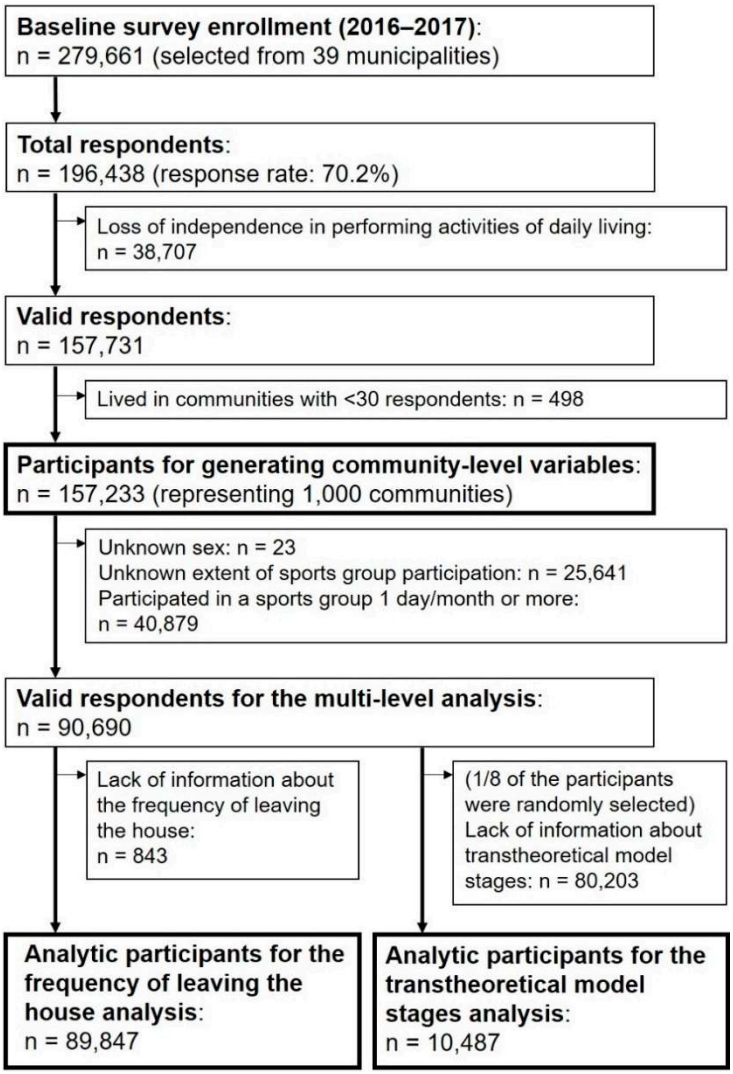

Figure 1. Flow of participants throughout the study.

Table 1. Characteristics of the participants.

	Analytic Participants for the Frequency of Leaving the House Analysis		Analytic Participants for the Transtheoretical Model Stages Analysis	
	n	%	*n*	%
Total	89,847	100.0%	10,487	100.0%
Sex				
Men	45,847	51.0%	5356	51.1%
Women	44,000	49.0%	5131	48.9%
Age (years)				
65–69	30,924	34.4%	3713	35.4%
70–74	24,108	26.8%	2791	26.6%
75–79	18,821	20.9%	2166	20.7%
80–84	10,698	11.9%	1232	11.7%
≥85	5296	5.9%	585	5.6%

Table 1. *Cont.*

	Analytic Participants for the Frequency of Leaving the House Analysis		Analytic Participants for the Transtheoretical Model Stages Analysis	
	n	**%**	***n***	**%**
Disease status in treatment				
No	17,593	19.6%	2117	20.2%
Yes	69,631	77.5%	8093	77.2%
Missing	2623	2.9%	277	2.6%
Living with others				
Yes	76,657	85.3%	8957	85.4%
No (living alone)	9873	11.0%	1161	11.1%
Missing	3317	3.7%	369	3.5%
Drinking status				
None	43,819	48.8%	5062	48.3%
Past	10,228	11.4%	1201	11.5%
Current	34,504	38.4%	4066	38.8%
Missing	1296	1.4%	158	1.5%
Smoking status				
None	50,115	55.8%	5853	55.8%
Past	27,754	30.9%	3222	30.7%
Current	11,402	12.7%	1306	12.5%
Missing	576	0.6%	106	1.0%
Education (years)				
<10	29,024	32.3%	3230	30.8%
10–12	36,679	40.8%	4319	41.2%
≥13	23,142	25.8%	2831	27.0%
Missing	1002	1.1%	107	1.0%
Annual household equivalent income (Japanese Yen)				
<2,000,000	35,851	39.9%	4208	40.1%
2,000,000–3,999,999	28,200	31.4%	3327	31.7%
≥4,000,000	7970	8.9%	957	9.1%
Missing	17,826	19.8%	1995	19.0%
Frequency of leaving the house				
>1 day/week	82,483	91.8%		
≤1 day/week	7364	8.2%		
Transtheoretical model stages				
1. Precontemplation			4356	41.5%
2. Contemplation			1215	11.6%
3. Preparation			2822	26.9%
4. Action			365	3.5%
5. Maintenance			1729	16.5%
Mean (standard deviation)			2.4	(1.5)

Table 2. Characteristics of community-level variables (n = 1000).

Proportion of Sports Group Participants (%)		
Mean (standard deviation)	26.7	(7.6)
(Minimum–Maximum)	(2.0–50.5)	
Population Density (Persons Per km^2 of Inhabitable Area), *n*		
≥10,000	257	
7000–9999	258	
2500–6999	238	
<2500	247	
Mean Annual Household Equivalent Income (Japanese Yen), *n*		
≥2,713,000	249	
2,468,000–2,712,999	249	
2,250,010–2,467,999	249	
<2,250,010	249	
Missing	4	

Table 3. Point estimates and 95% confidence intervals (CIs) estimated from multilevel regression analyses in each model.

	Null Model		Crude Model		Adjusted Model [1]	
Outcome: mostly homebound (leaving the house 1 day/week or less) (number of communities = 1000, number of participants = 89,847)						
Fixed effects						
Proportion of sports group participants Per 10 percentage points, OR (95% CI)			0.82	(0.79–0.86)	0.94	(0.89–0.996)
Random effects						
Community-level variance						
Ωμ, (standard error)	0.102	−0.012	0.079	−0.011	0.065	−0.011
Proportional changes in variance, %			22.5		36.3	
Outcome: transtheoretical model stages of behavior change for exercise (number of communities = 988, number of participants = 10,487)						
Fixed effects						
Proportion of sports group participants Per 10 percentage points, *B* (95% CI)			0.09	(0.05–0.14)	0.06	(0.01–0.12)
Random effects						
Community-level variance						
Ωμ, (standard error)	0.026	−0.009	0.02	−0.009	0.016	−0.008
Proportional changes in variance, %			23.1		38.5	

OR: odds ratio, CI: confidence interval. [1] Adjusting for age, sex, population density, mean annual household equivalent income (community-level), disease status in treatment, living status, drinking status, smoking status, education, and annual household equivalent income (individual-level).

4. Discussion

To the best of our knowledge, this is the first study to assess the contextual relationship between community-level prevalence of sports group participation and health behavior in older individuals, particularly those who do not participate in a sports group. A 10-percentage point increase in community-level sports group participation was associated with a 6% reduction in the risk of being homebound and a 0.06 higher in the transtheoretical model stages of behavior change for exercise after adjusting for potential confounders. These favorable associations can occur at any age group in the older population.

Social contagion might be considered a pathway that confirmed the results of this study supporting our hypothesis. Sometimes the behavior spreading via the network can promote healthy lifestyle changes (e.g., the spread of smoking cessation) [23,24]. In relation to this study, in communities where sports group participation is active, even if individuals do not participate in the group, they may have numerous opportunities to watch or cheer during the activities or participate in occasional events. As a result, they have numerous opportunities to go out, which may increase their interest in engaging in exercise and sports. Furthermore, Seino and colleagues have reported that community-level informal neighbor relationships were positively associated with individual-level moderate-to-vigorous physical activities among older men [25]. Both social participation, such as that in sports groups, and neighbor relationships are categorized as structural social capital; the affluence of this type of resource may enhance the frequency of going out and physical activities among older individuals living in the community.

Another possible pathway is collective efficacy, which is the group-level analog of the concept of self-efficacy and refers to the ability of the collective to mobilize to undertake a collective action [12,26,27]. Facilities, built environment, industries, systems, and bylaws for health promotion may develop to reflect the opinions and actions of communities with numerous sports groups and their participants. The group-level mechanisms of widespread sports group participation may result in positive spillover effects [9].

The transtheoretical model of behavior change is an integrative theory of therapy providing strategies or processes of change to guide an individual [14]. The strategies for enhancing the stages are mostly individual-oriented approaches, such as raising an individual's consciousness and enhancing self-efficacy [28–30]. Naturally, the importance of controlling the environment is also mentioned; however, it is focused on the environment relatively close to an individual, which directly correlated with their consciousness and activities. A systematic review assessing the efficacy of dietary or physical activity interventions based on the transtheoretical model stages of behavior change in overweight and obese individuals has reported that the interventions led to sustained weight loss during the intervention period [15]. Another review has concluded that the transtheoretical model is a useful and suitable behavior model in creating, developing, and evaluating interventions to acquire and improve physical activity habits in older individuals [29]. However, evidence about whether such interventions could improve the stages of behavioral change and sustain them over time is limited. Meanwhile, the results of this study indicated that the stages may be improved by arranging a community environment where sports groups are active, even without working on older individuals directly. Assuming that there are 10-percentage points for more sports group participants in the community area, then 6 of 100 non-participants living in the area will be one stage higher. The accumulation of this clinical significance would not be a negligible contribution to public health.

The study strength is its large, nationwide, population-based sample enabling community- and individual-level multilevel analyses for clarifying the contextual relationship of sports group participation limited only to non-participants in a sports group. However, this study had several limitations. First, reverse causality could occur because of the nature of the cross-sectional design, and longitudinal studies must be conducted to resolve this limitation. Second, selection bias might have affected the results due to the relatively low response rate at 70.2%. According to our previous study, the response rate and percentage of sports group participants with older age were significantly lower than those with younger age [31]. Therefore, the participants in this study might be relatively at low risk of homeboundness and might stay at high transtheoretical model stages of behavior change for exercise, and those relationships might have been underestimated. Third, the frequency of leaving the house and the transtheoretical model stages of behavior change for exercise are assumed to be associated with the levels of physical activity/inactivity; however, we did not collect the information using a valid index. If we evaluate the levels of physical activity/inactivity, we could further define the pathway linking community-level sports group participation and health outcomes among older individuals living in the community. Fourth, we could

not consider the geographic characteristics of the communities which could contribute to physical activity [32]. This might be one of the unmeasured confounders and diminish the relationships identified in this study.

5. Conclusions

Older individuals, even those who do not participate in a sports group, living in a community area with a high prevalence of sports group participation were less likely to be homebound and have higher transtheoretical model stages of behavior change for exercise than those living in an area with a low prevalence of participation. Promoting sports groups in a community may be an effective population-based strategy for increasing the frequency of leaving the house and enhancing interest in and providing opportunities to engage in exercise and sports even for non-participants in a sports group. A policy to increase sports groups, giving priority to communities where many older individuals with health problems live, may be effective.

Supplementary Materials: The following are available online at https://www.mdpi.com/1660-4601/18/2/531/s1, Table S1: All point estimates and 95% confidence intervals estimated from multilevel regression analyses in the fully adjusted model. Table S2: Point estimates and 95% confidence intervals (CIs) estimated from multilevel regression analyses stratified by age groups.

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Institutional Review Board Statement: Ethical approval for the study was obtained from the Ethics Committee at of Chiba University, Japan (Approval number: 2493) and the National Center for Geriatrics and Gerontology, Japan (Approval number: 992).

Informed Consent Statement: JAGES participants were informed that participation in the study was voluntary and that completing and returning the questionnaire via mail indicated their informed consent to participate in the study.

Data Availability Statement: Data are from the JAGES study. All enquiries are to be addressed at the data management committee via e-mail: dataadmin.ml@jages.net. All JAGES datasets have ethical or legal restrictions for public deposition due to inclusion of sensitive information from the human participants.

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ORIGINAL ARTICLE

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Social participation and mortality according to company size of the longest-held job among older men in Japan: A 6-year follow-up study from the JAGES

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Abstract

Objectives: The purpose of this study was to examine the relationship between social participation (type/pattern) and mortality according to company size of the longest-held job among older men in Japan who have worked in the company.

Methods: Longitudinal data from the Japan Gerontological Evaluation Study were used in this study. Functionally independent individuals aged 65 years and older in Japan were surveyed. Work and community organizations (local community, hobbies, and sports) were used as social participation. A Cox proportional hazards model was used to calculate mortality hazard ratios.

Results: Analysis was carried out on 19 260 participants. A total of 2870 deaths occurred during the 6-year follow-up period. Those in companies with 49 or fewer employees had the highest prevalence of work participation and the lowest participation in any community organization. Regardless of company size, the mortality risk was significantly lower for participants in any social participation (eg, the hazard ratio for participation in a hobby organization among those with a company size of 49 employees or fewer was 0.74, 95% CI: 0.65-0.85) compared to nonparticipants whose company size was 49 or fewer employees.

Conclusions: In Japan, although older men who have worked for small companies may have fewer benefits, their social participation may reduce their mortality risks.

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To avoid increasing health inequalities, it is necessary to create an environment in which they are more likely to participate in social activities.

KEYWORDS

community participation, health status disparities, leisure activities, social environment, work

1 | INTRODUCTION

Reducing health inequalities is a global challenge identified by the WHO General Assembly in 2009.[1] In Japan, which is the world's longest-lived country, health inequalities are widening because of the widening socioeconomic inequalities in recent years.[2,3] The reduction in health inequalities in Japan is listed as one of the basic directions to be achieved in the second term of the National Health Promotion Plan in the twenty-first century [Health Japan 21 (the second term)].[4]

Company size can be linked to health inequalities attributable to the differences in health services and social protections across companies.[5] In Japan, there are structural differences in the access stemming from the Industrial Safety and Health Act[6]; for large companies, the Act mandates to have industrial physicians, but it is not so for the smallest: workplaces with less than 50 employees. In addition, smaller companies have less health and safety activities,[6] lower average salaries,[7] poorer lifestyles,[8] and various health checkup results.[8] Long-term exposure to such differences in company size may cause health inequalities in old age. In fact, the smaller the size of the company where older men have worked the longest (company size of the longest-held job), the higher the risk of both death[9] and lesser instrumental activities of daily living.[10] However, none of the relationships were found for women in these two longitudinal studies. These results suggest that the influence of the company size of the longest-held job is limited to older men.

On the other hand, social participation of older adults is the key to successful aging.[11] Previous cohort studies suggest that social participation such as working[12] and participation in community organizations like local communities, hobbies, and sports[13] reduce mortality risk. However, since the relationship between social relationships, including social participation and health outcomes, varies depending on the socioeconomic status,[14,15] the relationship between social participation and mortality risk may also differ depending on the company size of the longest-held job which is closely associated with socioeconomic status. In terms of health inequalities,[16] it is necessary to clarify whether social participation lowers mortality risk even among older men who have worked for long periods in small companies that are most disadvantaged for mortality risk.

The purpose of this study was to examine the relationship between social participation (type/pattern) and mortality according to the company size of the longest-held job among older men in Japan who have worked in the company.

2 | MATERIALS AND METHODS

2.1 | Study design and participants

A population-based prospective cohort study was conducted in Japan. It was based on a sample from the Japan Gerontological Evaluation Study (JAGES).[17,18] The survey was sent to 95 827 individuals over the age of 65 years who were not certified for long-term care at baseline. It was carried out in 13 municipalities from August 2010 to January 2012. Participants were randomly selected from each municipality. The certification for long-term care is based on a national standard for long-term care assessment,[19] and the local government records who have been certified. Among the participants who responded to the baseline survey, those with invalid responses for ID number, age, and/or gender were excluded. Participants were followed for almost 6 years (a maximum of 6.6 years). Those who did not answer the question about the company size of the longest-held job, who responded "I don't know" or "I have never had a job" to the question about company size, or who responded "I have never had a job" to the question about the type of longest-held job were excluded. In addition, agriculture/forestry/fishery workers are mostly self-employed[20,21]; therefore, they were excluded from the analysis. Of the remaining subjects, only men were included in the analysis.

This study was conducted in accordance with the Helsinki Declaration. Ethical approval for the study was obtained from the Nihon Fukushi University Ethics Committee (application number: 10-05), the National Center for Geriatrics and Gerontology (application number: No. 992-2), and Chiba University Ethics Committee (application number: No. 2493), with participants' consent implied by the return of the questionnaires.

2.2 | Measures

2.2.1 | Mortality outcome

Death records from 2010 to 2016 (maximum: 6.6 years) were used from the municipal government database of public long-term care insurance.

2.2.2 | Social participation

Type of social participation

Participation in working[12] and community organization such as local community, hobbies, and sports,[13] which is related to decreased mortality risk, was used as social participation. Participants were asked, "What is your current working status?". Choices were "I have a paid job", "I am retired from my job", and "I have never had a job." Among these choices, "I have a paid job" was treated as "participation" in working. For neighborhood association or residents' association (local community), leisure activity group (hobbies), and sports group or club (sports), the frequency of participation was asked. Choices were "almost every day", "two or three times a week", "once a week", "once or twice a month", "a few times a year", or "never." Among these choices, "almost every day", "two or three times a week", "once a week", "once or twice a month", and "a few times a year" were treated as "participation."

Pattern of social participation

Based on previous studies on social participation,[22-24] the four types of social participation were categorized as work and community organizations (local community, hobbies, and sports). The four patterns of social participation were then classified into the following four categories: (a) those who are only working are "work-only"; (b) those who participate only in community organization (one or more of local community, hobbies, and sports) are "community organization-only"; (c) those who are working and participating in both and community organizations were designated as "both participation"; and (d) those who did not participate in both were designated as "both not participation."

2.2.3 | Company size of the longest-held job

Based on Japanese General Social Surveys,[25] the indicator for the company size of the longest-held job was developed. Participants were asked, "Of all your jobs to date, about how many people worked in the entire company or organization where you were employed the longest?" Choices were 1-9 employees, 10-49 employees, 50-499 employees, 500-9999 employees, 10 000 employees or more, "I don't know", and "I have never had a job." To obtain statistical power, 1-9 employees and 10-49 employees were categorized as "49 employees or less"; and 500-9999 employees and 10 000 employees or more were categorized as "500 or more." The reason for using this classification is that occupational health physicians (possibly part-time) and health supervisors in workplaces of 50 or more employees and full-time occupational health physicians in workplaces of 500 employees who are constantly in hazardous work are required to be employed as per the Industrial Safety and Health Act in Japan.[26]

2.2.4 | Covariates

Based on previous studies on the relationship between social participation and mortality,[12,13] the following were used as covariates: age (65-69 years, 70-74 years, 75-79 years, 80 years, and 85 years or more), annual equivalized income (less than 2 million yen per year = "low"; 2-3.99 million yen per year = "middle"; or 4 million yen or more per year = "high"), educational attainment (less than 6 years, less than 9 years, 10-12 years, or more than 12 years), type of longest-held job (professional/technical or administrative, clerical or sales/service, skilled/labor, or others[10]), municipalities, household composition (living alone or with others), body mass index (BMI: less than 18.5, 18.5 to 24.9, or 25.0 or more), and self-reported medical conditions (cancer, heart disease, stroke, hypertension, diabetes mellitus, hyperlipidemia, joint disease/neuralgia, respiratory disease, and psychiatric disease: yes or no for each medical condition).

2.3 | Statistical analyses

Analysis of variance and chi-square test were used to test the relationship between the company size of the longest-held job and characteristics at baseline. The Cox proportional hazards model was used to calculate mortality hazard ratios (HRs). We created an independent variable that combined social participation with company size to conduct the analysis. At this time, the reference category was nonparticipants with a company size of 49 employees or fewer. Respondents who were lost to follow-up because they relocated were censored. Model 1 was adjusted for age, annual equivalized income, educational attainment, type of longest-held job, municipalities, household composition, BMI, and self-reported medical conditions (cancer, heart disease, stroke, hypertension, diabetes mellitus, hyperlipidemia, joint disease/neuralgia, respiratory disease, and psychiatric disease). Model 2 was adjusted for the covariates in Model 1 plus the company size of the longest-held job. Furthermore, a sensitivity analysis, the analysis excluding those who died within 2 years, was performed to reduce the possibility of reverse causation. They were more likely to be functionally impaired to the extent that they could not participate in social activities at the time of the survey, and excluding them weakened the possibility of reverse causation.

Missing data were replaced with a dummy variable. Statistical significance was set at $P < .05$. All statistical analyses were conducted using IBM SPSS version 21.0.

3 | RESULTS

Figure 1 shows a flowchart of participants. Of the 95 827 individuals included in the baseline survey, responses were received from 62 426 individuals. Of these subjects, those who met the exclusion criteria were removed, and the remaining 19 260 subjects were analyzed. The number of people according to the company size of the longest-held job was 7487 (38.9%) for 49 or fewer employees, 5285 (27.4%) for 50-499 employees, and 6488 (33.7%) for 500 or more employees. The average follow-up period was 5.5 ± 1.3 years, 5.5 ± 1.3 years, and 5.5 ± 1.2 years, respectively. The mortality rate per 1000 person-years was 28.0, 25.4, and 22.8, respectively.

Table 1 shows the characteristics of participants according to the company size of the longest-held job. Significant differences were found between company sizes in all variables, except age and a part of self-reported medical conditions. Similarly, significant differences between company sizes were observed in any type and pattern of social participation. The highest prevalence of participation in work and the lowest prevalence of participation in each community organization were found in the group of 49 or fewer. With regard to the pattern of social participation, the largest difference between company sizes was in the prevalence of participation in "community organizations-only."

Figure 2 and Appendix S1 show mortality HRs for social participation according to the company size of the longest-held job. Participants in the work had a significantly lower mortality risk regardless of company size compared to non-participants with a company size of 49 employees or fewer. Similar relationships were also found in local communities, hobbies, and sports. However, among those with a company size of 49 employees or fewer, the significant difference in mortality HRs in only participants in work (HR = 0.87; 95% confidence interval = 0.74-1.02) and local community (0.90; 0.77-1.05) disappeared in the sensitivity analysis. Regarding the pattern of social participation, "work-only," "community organization-only," and "both participation" in any company size had significantly lower mortality risk than "both not participation" in a company size of 49 employees or fewer. In the sensitivity analysis, the significant difference in mortality HRs disappeared only for "work-only" whose company size was 49 employees or fewer (0.78; 0.60-1.03).

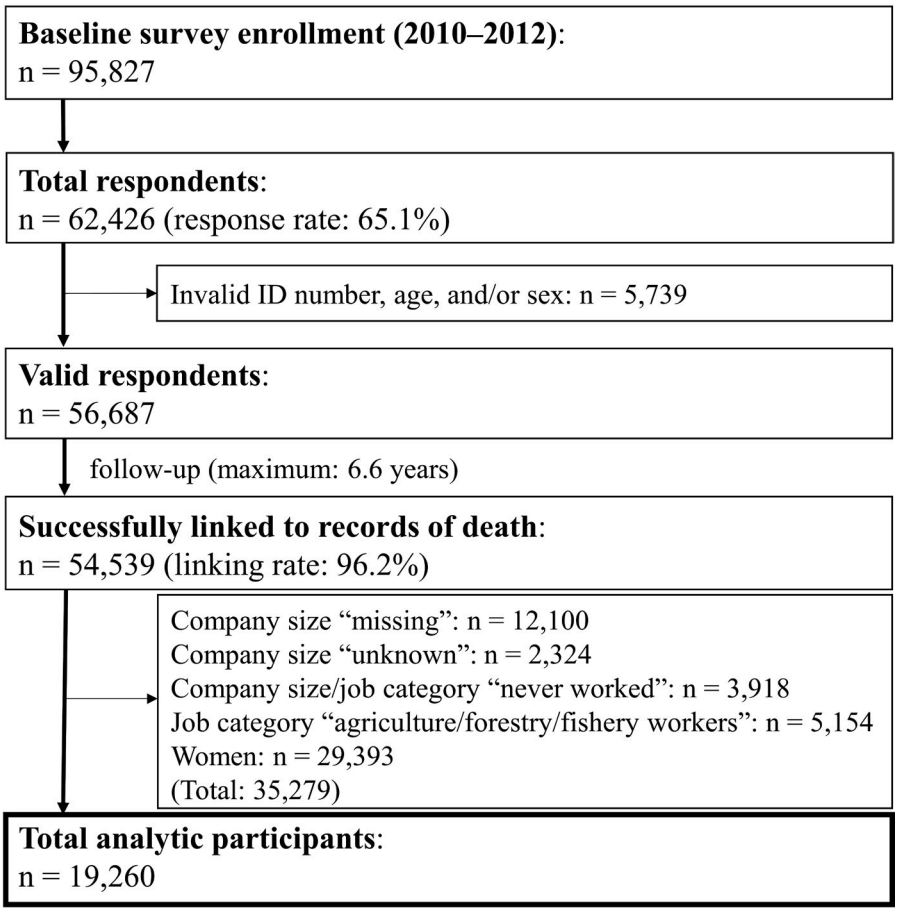


FIGURE 1 Flowchart of participants

TABLE 1 Characteristics of participants according to the company size of the longest-held job

	Company size of the longest-held job (number of employees)								
	Total (N = 19 260)		−49 (N = 7487)		50-499 (N = 5285)		500+ (N = 6488)		
	N	%	N	%	N	%	N	%	*P*
Age									
Mean ± SD	73.3 ± 5.7		73.4 ± 5.7		73.2 ± 5.7		73.2 ± 5.8		.07
Annual equivalized income									
Low	7633	39.6	3500	46.7	2184	41.3	1949	30.0	<.001
Middle	7570	39.3	2304	30.8	2003	37.9	3263	50.3	
High	2071	10.7	759	10.1	522	9.9	790	12.2	
Educational attainment									
Less than 6 y	221	1.1	128	1.7	56	1.1	37	0.6	<.001
6-9 y	7457	38.7	3691	49.3	2074	39.2	1692	26.1	
10-12 y	6497	33.7	2120	28.3	1862	35.2	2515	38.8	
13 y or more	4817	25.0	1433	19.1	1224	23.2	2160	33.3	
Type of longest-held job									
Professional/technical or administrative	7321	38.0	2504	33.4	1897	35.9	2920	45.0	<.001
Clerical or sales/service	4903	25.4	1834	24.5	1459	27.6	1610	24.8	
Skilled/labor	3969	20.6	1562	20.9	1116	21.1	1291	19.9	
Other	1899	9.9	1067	14.3	487	9.2	345	5.3	
Household composition									
Living alone	1435	7.4	619	8.3	436	8.2	380	5.9	<.001
With others	17 590	91.3	6762	90.3	4790	90.6	6038	93.1	
Body mass index									
Less than 18.5	1065	5.5	425	5.7	303	5.7	337	5.2	<.001
18.5-24.9	13 596	70.6	5103	68.2	3797	71.8	4696	72.4	
25.0 or more	4253	22.1	1768	23.6	1098	20.8	1387	21.4	
Self-reported medical conditions									
Cancer	1193	6.2	435	5.8	338	6.4	420	6.5	.261
Heart disease	2818	14.6	1109	14.8	784	14.8	925	14.3	.488
Stroke	376	2.0	161	2.2	87	1.6	128	2.0	.131
Hypertension	7274	37.7	2840	37.9	2004	37.9	2430	37.5	.525
Diabetes mellitus	2956	15.3	1145	15.3	848	16.0	963	14.8	.309
Hyperlipidemia	1493	7.7	496	6.6	377	7.1	620	9.6	<.001
Joint disease/Neuralgia	1384	7.2	605	8.1	368	7.0	411	6.3	<.001
Respiratory disease	890	4.6	359	4.8	284	5.4	247	3.8	<.001
Psychiatric disease	143	0.7	56	0.7	47	0.9	40	0.6	.270
Type of social participation									
Work	5154	26.8	2702	36.1	1223	23.1	1229	18.9	<.001
Local community	8218	42.7	2870	38.3	2372	44.9	2976	45.9	<.001
Hobbies	7688	39.9	2571	34.3	2020	38.2	3097	47.7	<.001
Sports	4866	25.3	1521	20.3	1326	25.1	2019	31.1	<.001

(Continues)

TABLE 1 (Continued)

	Company size of the longest-held job (number of employees)								
	Total (N = 19 260)		−49 (N = 7487)		50-499 (N = 5285)		500+ (N = 6488)		
	N	%	N	%	N	%	N	%	*P*
Pattern of social participation[a]									
Both not participation	3471	18.0	1342	17.9	1001	18.9	1128	17.4	<.001
Work only	1358	7.1	787	10.5	321	6.1	250	3.9	
Community organizations only	8265	42.9	2340	31.3	2410	45.6	3515	54.2	
Both participation	3301	17.1	1623	21.7	783	14.8	895	13.8	

Note: The analysis of variance and chi-square test were used to test the relationship between the company size of the longest-held job and characteristics.

Missing values for social participation have been omitted.

[a]Pattern of social participation: "work-only" means those who are only working; "community organization-only" means those who participate only in community organization (one or more of the local community, hobbies, and sports); "both participation" means those who participated in both and community organizations; and "both not participation" means those who did not participate in both.

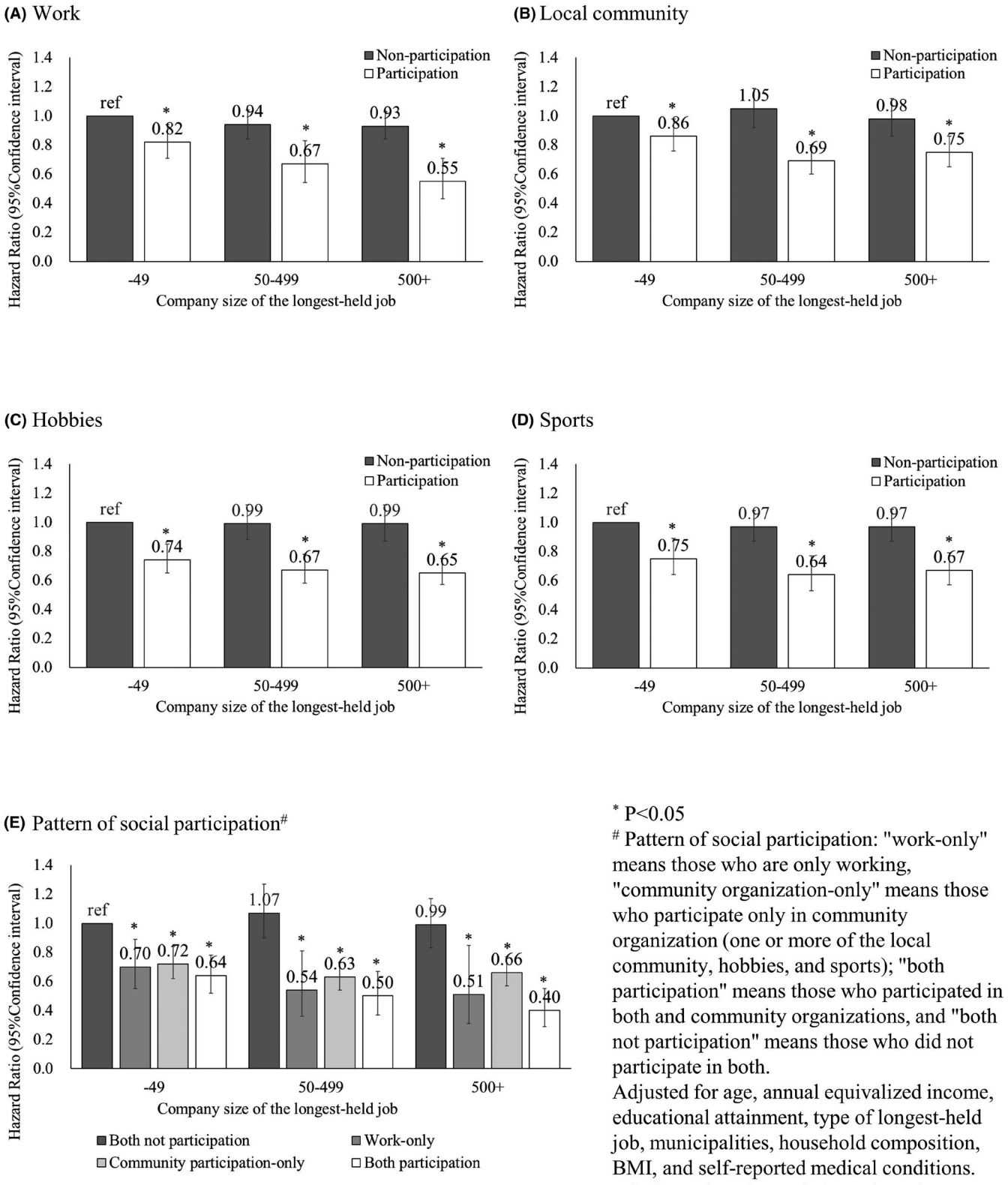
4 | DISCUSSION

This study examined the relationship between social participation (type/pattern) and mortality according to the company size of the longest-held job. Participants performing all types and patterns of social activities had a significantly lower risk of mortality regardless of company size compared to nonparticipants working in a company with less than 49 employees. There was no statistical difference in mortality risk between company sizes in the nonparticipation group for any type or pattern of social participation. However, the reduction in mortality risk in the participation group was smallest in those with a company size of 49 employees or fewer.

Previous studies have shown that participation in work and community participation are associated with a lower mortality risk among older adults,[12,13] and the results of this study are consistent with those of the previous studies. The present study also found that any social participation was associated with a lower mortality risk, even among socially disadvantaged groups of less than 49 employees. However, in a sensitivity analysis that excluded deaths within 2 years, significant differences disappeared for participation in work (0.87; 0.74-1.02), local community (0.90; 0.77-1.05), and work only (0.78; 0.60-1.03) in the group of 49 or fewer employees. The 95% confidence interval for these HRs may have slightly straddled 1 because of the reduction in statistical power by increasing the categories according to company size. Alternatively, those who worked at small companies could have participated in these organizations despite their ill health. Future studies should clarify these relationships by extending the sample size and follow-up period.

The reduction in mortality risk because of any social participation was smallest among those with a company size of 49 employees or fewer. This suggests that the health benefits of social participation were less for those who worked in small companies than for those who worked in large companies. A previous cohort study among older Japanese adults showed that those with longer education have a lower risk of functional disability because of social participation than those with shorter education.[15] The trend in the results of the present study is consistent with the findings of this previous study. Since it has been shown that those with higher levels of education can accumulate health capital more effectively than those with lower levels of education,[27] the low mortality risk because of social participation may have been smaller in a group of small companies with a greater number of those with shorter education histories.

Among our study participants, those who worked in the workplace with 49 or fewer workers were the most likely to continue working but the least likely to participate in community organizations (local community, hobbies, and sports). In the present study, educational attainment and income were associated with company size, and these factors may contribute to the association between company size and participation in community organizations. This is in concordance with other studies in Japan that observed different age groups. For example, previous research on Japanese workers aged 55-59 years shows that those who work for larger companies are less willing to work at older ages.[28] Results of this previous study support the differences in the proportion of work participation across company sizes in this study. A new finding in this study is that the company size of the longest-held job is associated with working status in older age. It has also been shown that those who do not own a home, have a mortgage, or have small savings accounts are more willing to work longer.[28] Average income is lower for smaller companies,[7] which may reflect the fact that employees working in smaller groups of companies are forced to work even after retirement. On the



* P<0.05
# Pattern of social participation: "work-only" means those who are only working, "community organization-only" means those who participate only in community organization (one or more of the local community, hobbies, and sports); "both participation" means those who participated in both and community organizations, and "both not participation" means those who did not participate in both.
Adjusted for age, annual equivalized income, educational attainment, type of longest-held job, municipalities, household composition, BMI, and self-reported medical conditions. Missing values for each factor have been omitted.

FIGURE 2 Mortality hazard ratios for social participation according to the company size of the longest-held job

other hand, previous study with middle-aged Japanese adults has shown that education attainment and lifestyle orientation are positively associated with social participation in sports and leisure activities.[22] Previous study among older Japanese adults has also shown that education attainment and income are positively associated with participation in sports groups.[29]

There are several implications for occupational and community health practitioners and policymakers. At the individual level, one of them is to encourage some forms of social participation (either through work or community organizations) in old age. At the policy level, a perspective of proportionate universalism, which strengthens measures in proportion to the weakness of the social position, is important.[30] Older men who have worked in smaller companies have a higher mortality risk compared to older men who have worked in larger companies and are less likely to participate in community organizations that may reduce their mortality risk. Furthermore, the health benefits of social participation for men who worked in small companies may be smaller than for men who worked in large companies, and it is feared that the current approach contributes to increasing health inequalities. Therefore, it is particularly important to create an environment that encourages their participation. In addition, since social participation in old age is associated with community involvement from middle age,[31] a preretirement approach is also key. In Japan, the guidelines for promoting cooperation between organizations in charge of community health and those responsible for employees' health were revised in 2019.[32] One of the initiatives is to promote engagement with under-supported segments of the population, such as small companies. The implications of this study should be reflected in such measures.

This study has several limitations. The first is that it does not necessarily reflect the overall picture of men who have worked in the company among the surveyed population. This is because the response rate of the questionnaire was 65.1%, and it was not possible to accurately disaggregate those who had worked in the company. It is possible that those whose longest-held jobs were self-employed or government employees were included in the analysis, although we excluded agriculture/forestry/fishery workers, who are often self-employed, from the analysis. Second, survival bias may have affected the results of this study. The risk of mortality was higher among older men who have worked for small companies, or among those who did not participate in work or community organizations. They are more likely than others to die prior to the study and may have been selectively omitted from the study population. For this reason, the mortality risk from social participation among older men who have worked for small companies may be underestimated. Third, there may be a nondiscriminatory misclassification in the measure of the company size of the longest-held job. The questions on company size and job type may have been difficult to answer accurately because they asked about previous long-term employment. Therefore, the relationships observed in this study may have been underestimated. Fourth, we were unable to use information on causes of death and could not identify which causes of death social participation may specifically reduce the risk of death. Hence, we are unable to infer a mechanism for reducing mortality and differences between company sizes in the relationship between social participation and mortality risk.

In conclusion, regardless of the company size of the longest-held job (even if the company with fewer than 49 employees), older men in Japan who have worked in a company may be able to reduce their mortality risk through social participation, especially in hobbies and sports. However, the smaller the company size of the longest-held job, the smaller the benefit is likely to be. To avoid increasing health inequalities in old age according to the company size of the longest-held job, it is necessary to create an environment in which people who have worked in smaller companies are more likely to participate in social activities.

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CONFLICT OF INTEREST

Authors declare no conflict of interests for this article.

DISCLOSURES

Approval of the research protocol: The Research Ethics Committee of the Nihon Fukushi University Ethics

Committee (application number: 10-05) reviewed and approved the aims and procedures of this study. *Informed consent*: Informed consent was obtained from all individual participants included in the study. *Registry and the registration no. of the study/trial*: N/A. *Animal studies*: N/A.

AUTHOR CONTRIBUTIONS

SK conducted the analysis and wrote manuscript in collaboration with NK, T Takamiya, HK, and SI; and T Tsuji wrote the first draft of the manuscript. YK, GM, and KK provided the feedback and suggestions. All authors read the manuscript and approved to submission.

ETHICAL APPROVAL

Ethical approval for the study was obtained from the Nihon Fukushi University Ethics Committee (application number: 10-05). This study was performed in accordance with the principles of the Declaration of Helsinki. Informed consent was obtained from all participants.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the Supporting Information section.

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Effect of Copayment on Dental Visits: A Regression Discontinuity Analysis

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Abstract

Despite their prevalence and burdens, oral diseases are neglected in universal health coverage. In Japan, a 30% copayment (out of pocket) by the user and a 70% contribution by Japan's universal health insurance (JUHI) are required for dental and medical services. From the age of 70 y, an additional 10% is offered by JUHI (copayment, 20%; JUHI, 80%). This study aimed to investigate the effect of cost on dental service use among older adults under the current JUHI system. A regression discontinuity quasi-experimental method was used to investigate the causal effect of the JUHI discount policy on dental visits based on cross-sectional data. Data were derived from the 2016 Japan Gerontological Evaluation Study. This analysis contained 7,161 participants who used JUHI, were aged 68 to 73 y, and responded to questions regarding past dental visits. Analyses were controlled for age, sex, number of teeth, and equalized household income. Mean ± SD age was 72.1 ± 0.79 y for the discount-eligible group and 68.9 ± 0.78 y for the noneligible group. During the past 12 mo, significantly more discount-eligible participants had visited dental services than noneligible participants (66.0% vs. 62.1% for treatment visits, 57.7% vs. 53.1% for checkups). After controlling for covariates, the effect of discount eligibility was significant on dental treatment visits (odds ratio [OR], 1.36; 95% CI, 1.32 to 1.40) and dental checkups (OR, 1.49; 95% CI, 1.44 to 1.54) in the regression discontinuity analysis. Similar findings were observed in triangular kernel-weighted models (OR, 1.38 [95% CI, 1.34 to 1.44]; OR, 1.52 [95% CI, 1.47 to 1.56], respectively). JUHI copayment discount policy increases oral health service utilization among older Japanese. The price elasticity for dental checkup visits appears to be higher than for dental treatment visits. Hence, reforming the universal health coverage system to improve the affordability of relatively inexpensive preventive care could increase dental service utilization in Japan.

Keywords

dental public health, health services research, epidemiology, behavioral science, access to care, prevention

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Social Participation and Functional Decline: A Comparative Study of Rural and Urban Older People, Using Japan Gerontological Evaluation Study Longitudinal Data

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Abstract: This study compared the relationship between social participation, including work, and incidence of functional decline in rural and urban older people in Japan, by focusing on the number and types of organizations older people participated in. The longitudinal data of the Japan Gerontological Evaluation Study (JAGES) that followed 55,243 individuals aged 65 years or older for six years were used. The Cox proportional hazards model was employed to calculate the hazard ratio (HR) of the incidence of functional decline over six years and the stratification of rural and urban settings. In this model, we adjusted 13 variables as behavioral, psychosocial, and functional confounders. The more rural and urban older people participated in various organizations, the more they were protected from functional decline. Participation in sports (HR: rural = 0.79; urban = 0.83), hobby groups (HR: rural = 0.76; urban = 0.90), and work (HR: rural = 0.83; urban = 0.80) significantly protected against the incidence of decline in both rural and urban areas. For both rural and urban older people, promoting social participation, such as sports and hobby groups and employment support, seemed to be an important aspect of public health policies that would prevent functional decline.

Keywords: social participation; work; functional decline; rural; urban

1. Introduction

A strategy of active ageing [1], by linking the key policy domains of employment, pension, retirement, health, and citizenship, provides a sound basis to respond to the challenges presented by population ageing [2]. In recent times, the practical challenge has been to open up the innovative policy

spaces that might make active ageing not only thinkable but also achievable [3]. In European countries, the Active Aging Index (AAI) tool measures the untapped potential of older people for active and healthy aging across countries [4]. The AAI consists of four domains: employment, participation in society; independent, healthy, and secure living; and capacity and enabling environment for active ageing [4,5].

The social participation of older people, one of the domains of AAI [4,5], is a key factor of "successful aging" [6] and an important element of "active aging" [7]. Social participation is one of the core indicators of "age-friendly cities" proposed by the World Health Organization in recent years [8]. When considering public health services in a rapidly aging society, social participation is highlighted as a modifiable target of health interventions.

In many longitudinal studies, social participation has been reported as effective for health outcomes such as functional disability [9–13], cognitive disability [14–16], instrumental activities of daily living decline [17–19], and basic activities of daily living decline [20]. Among them, some studies focused on the number and types of organizations in which older people participated [10,13,16–18]. These studies suggested that older people who participate in more organizations are healthier than those who do not participate, and that the relationships between social participation and health varied according to the types of organization they participate in.

However, these studies [10,13,16–18] do not consider two issues. First, these studies do not consider "work" as a kind of social participation. According to the Organization for Economic Co-Operation and Development (OECD) scoreboard for older workers, older workers aged 65–69 years increased from 20.3% to 25.5% between 2006 and 2016 and from 12.0% to 14.6% at age 70–74 years during the same period, in OECD member countries [21]. However, recommendations made by the Council on Aging and Employment Policies [22] encourage supporting the employment of older people. In AAI, work and social participation are separate domains, but these are also defined as the actual experience of active aging [4,5]. Considering these circumstances, it is necessary to include work in social participation in the analysis of the number and types of organizations in which older people participated. Second, these studies do not consider residential environments, such as rural and urban areas. Generally, older people living in rural areas suffer with more depression [23], lower levels of basic activities of daily living [20], and a higher risk of developing disability [24] compared to those living in urban areas. In addition, the life expectancy is shorter in rural areas, and the difference between urban and rural areas is widening [25]. Previous studies [13,26] showed that rural older people were less socially active than urban older people. However, previous studies state that bonding social capital comprising a connection between community members is often stronger among rural older adults, resulting in community strength [27,28]. In addition, environmental factors such as neighborhood socioeconomic status and access to services and transportation differ in rural and urban areas [29]. Furthermore, the relationship between social participation and health outcomes, such as depression [23] and self-rated health [26,30], also differs. These may be the reasons why rural older people are unhealthier than urban older people. The relationship between social participation and functional decline may differ between rural and urban areas; however, such a relationship has not been clarified.

Thus, we aimed at clarifying whether there were differences between rural and urban areas in the relationship between social participation, including work, and incidence of functional decline. This study was conducted to inform public health policies that could prevent the need for long-term care of older individuals residing in rural and urban areas, which have different environmental factors.

2. Materials and Methods

2.1. Data

We used longitudinal data from the Japan Gerontological Evaluation Study (JAGES). JAGES is one of the few population-based gerontological repeated surveys in Japan focused on the social

determinants of health and the social environment [31,32]. From August 2010 to January 2012, self-reported questionnaires were mailed to 95,827 community-dwelling independent individuals aged 65 years and older who were not eligible to receive benefits from public long-term care insurance services. They were randomly selected from 13 municipalities, including rural and urban areas. Overall, 62,418 people participated (response rate, 65.1%) in the survey called JAGES2010. They were followed up for about six years (minimum 5.2 years; maximum 6.4 years). Of the total respondents (response rate 65.1%), 54,539 (87.4%) were successfully linked to the incident records of long-term care insurance certification. We excluded 7223 responses for the following reasons: (i) missing information on address (n = 101) and activities of daily living (ADL) (n = 1482); and (ii) having physical or cognitive disabilities reported in their questionnaires (n = 988). Moreover, 4662 respondents in long-term care within two years were removed to avoid the possibility of reverse causality (i.e., the possibility that people who were at high risk of functional decline did not participate socially). The final number of participants in this analysis was 47,306.

Ethical approval for the study was obtained from the Nihon Fukushi University Ethics Committee (application number: 10–05), the National Center for Geriatrics and Gerontology (application number: No. 992-2), and Chiba University Ethics Committee (application number: No. 2493).

2.2. Dependent Variable

The dependent variable was the incidence of functional decline during the follow-up period. The incidence of functional decline was defined by medical certification for Long-Term Care Insurance. Certification of decline is based on the formal evaluation of the need for Long-Term Care according to uniform criteria applied throughout Japan, and comprises both a home-visit interview, as well as the written opinion of a primary physician [33]. This formal evaluation is based on a standardized multistep assessment of functional and cognitive impairments [33]. We obtained information on the certification of long-term needs, death, and moving out of the study area, from the long-term care insurance database maintained by the municipalities. These criteria for determining the onset of functional decline have been used in previous epidemiological studies [4–6].

2.3. Independent Variable

The independent variable was social participation. With reference to previous research [5], social participation was classified into the following six types: neighborhood groups (local community), hobby groups (hobby), sports groups or clubs (sports), industrial groups (industry), volunteer groups (volunteer), and senior citizen clubs (citizen). Furthermore, we considered work (work) as a form of social participation and therefore analyzed seven types of organizations in this study.

Participation in organizations other than work was assessed by using the following question: "How often do you participate in the following clubs or groups?". Participants were given the following choices: "almost every day", "twice or thrice a week", "once a week", "once or twice a month", "a few times a year" and "never". The response was categorized as "yes" if individuals selected any of the five options from "a few times a year" to "almost every day", and "no" if they selected "never". Participation in work was assessed by using the following question: "What is your current working status?". Participants were given the following choices: "working", "retired and not working now" and "never had a job". The response was categorized as "yes" if the participants answered "working", and "no" if they answered "retired and not working now" or "never got a job".

The total number of types of organizations each participant participated in was tallied, and participation was categorized as 0 (no participation), 1, 2, or ≥3 organizations, or "missing". If the response to participation in all organizations was missing, we deemed it as "missing" category in this analysis. The organizations particularly unique to Japan among the types named above are senior citizen clubs. Japan's senior citizens clubs conduct a wide range of activities, including group activities such as sports, hobbies, cultural activities, and performing arts.

2.4. Covariates

Based on a previous study [10], sex, age, annual equivalized income, educational attainment, marital status, and self-reported medical conditions were considered potential confounding factors that may correlate with social participation and incidence of functional disability. In addition, behavioral, psychosocial, and physiological factors were also used as covariates and potential mechanisms influencing health and social participation. Smoking, alcohol consumption, daily walking time, and frequency of going outdoors were assessed as behavioral factors. Depression (Geriatric Depression Scale), emotional support, instrumental support, and frequency of meeting friends were assessed as psychosocial factors. Instrumental activity of daily living (IADL) was assessed as a functional factor. All variables were categorized as shown in Table 1 and set as dummy variables. A "missing" category was used in the analysis to account for missing responses to questions.

2.5. Classification of Rural and Urban Settings

The definition of functional urban areas from the OECD metropolitan database [34] was used to classify rural and urban settings. The definition of urban areas in OECD countries uses population density to identify urban cores, and travel-to-work flows to identify the hinterlands whose labor market is highly integrated with the cores. The methodology consisted of the three following main steps: (1) identification of core municipalities through gridded population data; (2) connecting noncontiguous cores belonging to the same functional urban area; and (3) identification of urban hinterlands. This methodology makes it possible to compare functional urban areas of similar size across different countries and classifies functional urban areas according to population size into the following four types: (1) small urban areas (with a population below 200,000 people); (2) medium-sized urban areas (with a population between 200,000 and 500,000); (3) metropolitan areas (with a population between 500,000 and 1.5 million); and (4) large metropolitan areas (with a population of 1.5 million or more). From the OECD's four functional urban areas, all cities, including metropolitan and large metropolitan areas, were designated urban areas in this study, and all others were designated rural areas. In this study, eight municipalities were designated as rural, and five municipalities were designated as cities.

2.6. Statistical Analysis

First, we conducted a chi-square test to compare variables between rural and urban males and females. As the sample size in this study is very large, we calculated Cramer's V as the effect size in addition to the *p*-value. The criteria for Cramer's V are 0.1 for small, 0.3 for medium, and 0.5 for large. Second, the Cox proportional hazards model was employed to calculate the hazard ratios (HRs) and 95% confidence intervals (CI) of the incidence of functional decline over six years, stratified by rural, and urban settings. In each model, nonparticipation in an organization was set as the referent category. In the analysis of the number or types of organization older people participate in, we conducted a trend test. Further, six types of social participation were introduced in each model separately. The following two models of analysis were used: a regression analysis was performed with simultaneous forced entry of sex, age, equivalent income, educational attainment, marital status, and self-reported medical conditions as covariates (Model 1). Model 2 added the following confounding factors to Model 1: smoking, alcohol consumption, walking time, frequency of going outdoors, Geriatric Depression Scale, emotional support, instrumental support, frequency of meeting friends, and IADL. Finally, to confirm the robustness of our finding, we performed a complete case analysis, excluding patients missing any of the variables used in the analysis. STATA V.15 (Stata Corp, College Station, TX, USA) was used to conduct a statistical analysis, with a significance level of 5%.

Table 1. Baseline characteristics of respondents (2010–2012).

Variables		Rural (n = 15,083)		Urban (n = 32,223)		p-Value (Cramer's V)
		n	%	n	%	
Sex	Male	6758	44.8	15,163	47.0	<0.001
	Female	8325	55.2	17,063	53.0	(0.02)
Age (years)	65–69	4287	28.4	9676	30.0	<0.001 (0.04)
	70–74	4536	30.1	10,343	32.1	
	75–79	3470	23.0	7257	22.5	
	80–84	1973	13.1	3611	11.2	
	85+	817	5.4	1336	4.2	
Equivalent income (million yen)	Low (<2.0)	7127	47.3	11,815	36.7	<0.001 (0.13)
	Middle (2.0–3.9)	3988	26.4	11,321	35.1	
	High (≥4.0)	939	6.2	3616	11.2	
	Missing	3029	20.1	5471	17.0	
Educational attainment (years)	<10	8404	55.7	14,103	43.8	<0.001 (0.12)
	10–12	4432	29.4	11,182	34.7	
	≥13	1853	12.3	6255	19.4	
	Missing	394	2.6	683	2.1	
Marital status	Married	10,611	70.3	23,315	72.4	<0.001 0.04
	Single	4111	27.3	8480	26.3	
	Missing	361	2.4	428	1.3	
Self-reported medical conditions	Illness	10,267	68.1	21,859	67.8	0.243 (0.01)
	No illness	3508	23.2	7677	23.8	
	Missing	1308	8.7	2687	8.4	
Smoking	Never smoked	8440	56.0	17,174	53.3	<0.001 (0.04)
	Past smoker	3566	23.6	8649	26.9	
	Current smoker	1437	9.5	3330	10.3	
	Missing	1640	10.9	3070	9.5	
Alcohol consumption	Never drank	9122	60.5	18,420	57.2	<0.001 (0.03)
	Past drinker	440	2.9	1021	3.2	
	Current drinker	4684	31.1	10,836	33.6	
	Missing	837	5.5	1946	6.0	
Walking time (per day)	>90 min	2515	16.7	5004	15.5	<0.001 (0.05)
	60–90 min	2130	14.1	5029	15.6	
	30–60 min	4558	30.2	10,960	34.0	
	<30 min	4905	32.5	9341	29.0	
	Missing	975	6.5	1889	5.9	
Frequency of going outdoors	Almost everyday	6607	43.8	18,496	57.4	<0.001 (0.15)
	2–3 times/week	4601	30.5	8288	25.7	
	About once/week	1755	11.6	2253	7.0	
	Rarely	1351	9.0	1384	4.3	
	Missing	769	5.1	1802	5.6	
Depression	No depression	9313	61.8	19,977	62.0	0.002 (0.02)
	Depressive tendency	2613	17.3	5343	16.6	
	Depression	822	5.4	1595	4.9	
	Missing	2335	15.5	5308	16.5	
Emotional support	Available	13,052	86.5	28,584	88.7	<0.001 (0.03)
	Not available	1209	8.0	2310	7.2	
	Missing	822	5.5	1329	4.1	
Instrumental support	Available	12,369	82.0	26,971	83.7	<0.001 (0.03)
	Not available	1906	12.6	3906	12.1	
	Missing	808	5.4	1346	4.2	

Table 1. *Cont.*

Variables		Rural (*n* = 15,083)		Urban (*n* = 32,223)		*p*-Value (Cramer's V)
		n	%	*n*	%	
Frequency of meeting friends	Almost everyday	2247	14.90	4347	13.5	<0.001 (0.04)
	2–3 times/week	3513	23.30	7206	22.4	
	About once/week	2461	16.30	5293	16.4	
	1–2 times/month	2914	19.30	6049	18.8	
	A few times a year or less	2841	18.80	7251	22.5	
	Missing	1107	7.40	2077	6.4	
Instrumental activity of daily living (IADL)	Not decline	6073	40.3	12,578	39.0	0.025 (0.01)
	Decline	7230	47.9	15,856	49.2	
	Missing	1780	11.8	3789	11.8	
Number of types of organizations	0	3187	21.1	7700	23.9	<0.001 (0.06)
	1	3420	22.7	7964	24.7	
	2	2691	17.8	6173	19.1	
	≥3	5227	34.7	9588	29.8	
	Missing	558	3.7	798	2.5	
Type of social participation						
Local community	Nonparticipation	5909	39.2	14,781	45.9	<0.001 (0.07)
	Participation	5886	39.0	10,802	33.5	
	Missing	3288	21.8	6640	20.6	
Hobby	Nonparticipation	6656	44.1	13,411	41.6	<0.001 (0.05)
	Participation	5430	36.0	13,212	41.0	
	Missing	2997	19.9	5600	17.4	
Sports	Nonparticipation	8540	56.6	18,242	56.6	0.001 (0.02)
	Participation	3272	21.7	7375	22.9	
	Missing	3271	21.7	6606	20.5	
Industry	Nonparticipation	8791	58.3	19,293	59.9	<0.001 (0.04)
	Participation	2020	13.4	4829	15.0	
	Missing	4272	28.3	8101	25.1	
Volunteer	Nonparticipation	8787	58.3	19,803	61.5	<0.001 (0.03)
	Participation	2292	15.2	4526	14.0	
	Missing	4004	26.5	7894	24.5	
Citizen	Nonparticipation	7842	52.0	19,244	59.7	<0.001 (0.10)
	Participation	4247	28.2	6165	19.1	
	Missing	2994	19.8	6814	21.2	
Work	Nonparticipation	9002	59.7	21,572	67.0	<0.001 (0.10)
	Participation	3397	22.5	7166	22.2	
	Missing	2684	17.8	3485	10.8	

3. Results

Table 1 presents the descriptive statistics of rural and urban variables. Of the 47,306 respondents included in the analyses, 21,921 were male and 25,385 were female. Of the 21,921 males, 6758 lived in rural and 15,163 lived in urban settings. Of the 25,385 females, 8375 lived in rural and 17,060 lived in urban settings. The average age of the rural and urban older people was 73.8 (standard deviation (SD), 5.9) and 73.3 (SD, 5.6) years, respectively. Of the respondents in rural and urban areas, 2399 (15.9%) and 4018 (15.3%) reported functional decline, respectively. The average tracking period was 2028.1 days (SD = 364.1) for rural and 1951.8 days (SD = 361.7) for urban older peoples. The comparison of variables across rural and urban areas revealed that there were many urban–rural differences. However, the sample size for this study was so large that even minor differences could result in statistical differences. In fact, Cramer's V in the chi-square test between almost all variables was judged to be very small, and the realistic effect size was small. However, describing the difference

between rural areas and cities when the effect size is 0.1 or more indicated that older people in rural areas had a lower equivalent income ($p < 0.001$), lower educational attainment ($p < 0.001$), and went outdoors less frequently ($p < 0.001$) than those in urban areas. Although the effect size was small, the distribution of the number of organizations in which older people participated differed between rural and urban areas ($p < 0.001$). When types of social participation were analyzed, rural older people participated a lot more in senior citizen clubs ($p < 0.001$) than urban older people. The distribution of participation in work differed between rural and urban areas ($p < 0.001$; Cramer's V = 0.1); it was thought to be due to the missing category.

Table 2 presents the results of a Cox proportional hazards model analysis of the different types of organizations and incidence of functional decline. In the crude model and Model 1, a "dose–response" relationship was seen both among rural and urban areas, with progressively lower HRs as the number of different types of organizations increased. In Model 2 for rural older people, the HRs were 0.94 (95% CI: 0.84–1.05) for participation in one, 0.85 (0.75–0.97) for participation in two, and 0.76 (0.67–0.86) for participation in three or more different types of organizations, with the significant difference disappearing only for participation in one type of organization. For urban older people, the HRs were 0.92 (95% CI: 0.85–0.99) for participation in one, 0.87 (0.80–0.96) for participation in two, and 0.82 (0.75–0.89) for participation in three or more different types of organizations, with the statistical significance for one or more different types of organizations. In other words, older people in urban areas were protected from functional decline through one type of participation. On the other hand, older people in rural areas required more than one type of participation, but older people in rural areas had lower HRs when participating in more than two types of organizations than older people in urban areas.

Table 2. HRs for participation in one, two, and three or more different types of organizations.

Rural	Crude Model	Model 1	Model 2
	HR (95% CI)	HR (95% CI)	HR (95% CI)
0	1.00 Ref	1.00 Ref	1.00 Ref
1	0.71 * (0.64–0.79)	0.87 * (0.78–0.97)	0.94 (0.84–1.05)
2	0.57 * (0.50–0.64)	0.75 * (0.66–0.85)	0.85 * (0.75–0.97)
≥3	0.43 * (0.39–0.49)	0.62 * (0.56–0.70)	0.76 * (0.67–0.86)
Trend p	$p < 0.05$	$p < 0.05$	$p < 0.05$
Urban	**Crude model**	**Model 1**	**Model 2**
	HR (95% CI)	**HR (95% CI)**	**HR (95% CI)**
0	1.00 Ref	1.00 Ref	1.00 Ref
1	0.69 * (0.64–0.75)	0.85 * (0.79–0.91)	0.92 * (0.85–0.99)
2	0.59 * (0.55–0.65)	0.77 * (0.71–0.84)	0.87 * (0.80–0.96)
≥3	0.48 * (0.44–0.52)	0.67 * (0.62–0.72)	0.82 * (0.75–0.89)
Trend p	$p < 0.05$	$p < 0.05$	$p < 0.05$

HR: Hazard ratio; CI: confidence interval; Ref: reference. * $p < 0.05$. Model 1: Crude model + sex, age, equivalent income, educational attainment, marital status, and self-reported medical conditions. Model 2: Model 1 + smoking, alcohol consumption, walking time (per day), frequency of going outdoors, depression, emotional support, instrumental support, frequency of meeting friends, and IADL.

The results of the complete case analysis are shown in Table S1. The results of the complete case analysis, excluding patients missing any of the variables used in the analysis were similar to those when the "missing" category was used in the analysis to account for missing responses to questions. The full modeling results in Model 2 were presented in Table S2. In this study, Model 2 added social networks such as emotional support, instrumental support, and frequency of meeting friends. Rural and urban older people who could not avail emotional support were not protective against functional decline compared with those who could avail it. Furthermore, urban older people who could not avail instrumental support were not protective against functional decline compared with those who could

avail it, but this was not the case in rural areas. The frequency of meeting friends was not statistically significant in rural and urban areas.

Table 3 presents the results of the Cox proportional hazards model analysis of the type of social participation and incidence of functional decline. Almost all types of organizational participation were strongly protective against functional decline, but senior citizen clubs had the opposite relationship in the crude model. Similarly, many types of organizational participation were protective against functional decline in Model 1. In Model 2 for rural older people, participation in hobbies (HR = 0.76; 95% CI: 0.68–0.85), sports (HR = 0.79; 95% CI: 0.69–0.89), work (HR = 0.83; 95% CI: 0.76–0.91), and local community (HR = 0.86; 95% CI: 0.77–0.95) was found to be protective against the incidence of decline. For urban older people, participation in work (HR = 0.80; 95% CI: 0.70–0.91), sports (HR = 0.83; 95% CI: 0.77–0.91), and hobbies (HR = 0.90; 95% CI: 0.84–0.97) was found to be protective against the incidence of decline.

Table 3. HRs for type of social participation (reference: nonparticipation in each organization).

Rural	**Crude Model**	**Model 1**	**Model 2**
	HR (95% CI)	**HR (95% CI)**	**HR (95% CI)**
Local Community	0.59 * (0.54–0.65)	0.77 * (0.70–0.86)	0.86 * (0.77–0.95)
Hobby	0.57 * (0.52–0.64)	0.61 * (0.60–0.75)	0.76 * (0.68–0.85)
Sports	0.62 * (0.55–0.70)	0.70 * (0.62–0.78)	0.79 * (0.69–0.89)
Industry	0.67 * (0.58–0.78)	0.92 (0.84–1.01)	1.01 (0.87–1.18)
Volunteer	0.62 * (0.54–0.72)	0.77 * (0.67–0.89)	0.89 (0.77–1.03)
Citizen	1.40 * (1.27–1.54)	0.94 (0.85–1.03)	1.02 (0.93–1.13)
Work	0.48 * (0.42–0.54)	0.74 * (0.65–0.84)	0.83 * (0.76–0.91)
Urban	**Crude Model**	**Model 1**	**Model 2**
	HR (95% CI)	**HR (95% CI)**	**HR (95% CI)**
Local Community	0.70 * (0.65–0.75)	0.84 * (0.79–0.90)	0.95 (0.88–1.01)
Hobby	0.70 * (0.66–0.75)	0.78 * (0.73–0.84)	0.90 * (0.84–0.97)
Sports	0.60 * (0.55–0.65)	0.73 * (0.67–0.79)	0.83 *(0.77–0.91)
Industry	0.81 * (0.74–0.89)	0.90 (0.78–1.05)	1.04 (0.95–1.15)
Volunteer	0.66 * (0.60–0.73)	0.80 * (0.73–0.89)	0.94 (0.85–1.04)
Citizen	1.37 * (1.28–1.47)	0.89 * (0.83–0.96)	0.99 (0.92–1.07)
Work	0.50 * (0.46–0.55)	0.80 *(0.73–0.87)	0.80 * (0.70–0.91)

HR: Hazard ratio; CI: confidence interval; Ref: reference. * $p < 0.05$. Model 1: Crude model + sex, age, equivalent income, educational attainment, marital status, and self-reported medical conditions. Model 2: Model 1 + smoking, alcohol consumption, walking time (per day), frequency of going outdoors, depression, emotional support, instrumental support, frequency of meeting friends, and IADL.

The results of the complete case analysis are shown in Table S3. In the complete case analysis for rural older people, the HR for participation in work and local community was below 1.00, but the statistical significance disappeared. Further, the results of the complete case analysis for urban older people, excluding patients missing any of the variables used in the analysis, were similar to those when the "missing" category was used in the analysis, to account for missing responses to questions. The full modeling results in Model 2 were presented in Table S4. The result of the social networks, such as emotional support, instrumental support, and frequency of meeting friends, added in Model 2, was similar to the analysis of the number of organizations.

4. Discussion

To the best of our knowledge, this is the first longitudinal study to compare the relationship between the number and type of organizations, including work, and incidence of functional decline in rural and urban areas separately.

In all, two findings were obtained from this study: (1) a "dose–response" relationship was seen both among rural and urban areas, with progressively lower HRs as the number of different types of

organizations increased; and (2) participation in sports, hobbies, and work were protective against incidences of decline in both rural and urban areas. In this study the classification of rural and urban areas is as proposed by the OECD. Previous studies have used population density and national classification; however this study adopted an international classification system. Even when classifying areas by population density, the results of this study were almost the same.

The analysis of the number of organizations revealed the HRs of the number of types of organizations progressively decreased as the number of participating organizations. This supports previous studies, including those measuring other health outcomes [10,13,16–18]. In this study, HRs were lower when participated in two or more types of organizations in rural areas than in urban areas. The social relationships specific to rural areas may be the reason why older people living in these areas need to join more than one organization. Previous studies have indicated that bonding social capital comprising a connection between community members is often stronger among rural older adults, resulting in community strength [27,28]. In this study, participation in local community organizations was higher in rural areas than in urban areas. However, excessive bonding social capital tends to have negative effects [35]. According to the systematic review of the negative health effects of social capital [35], there are downsides to social capital that emerge in the context of strong bonding social capital, but not in weak bridging social capital. (1) Strong bonding ties impose heavy obligations on community members by following a dominant social hierarchy and social norms, and it exclude outsiders. (2) The lack of bridging SC is crucial in socioeconomically disadvantaged communities. (3) In such settings, the connection of members to outside sources of support is even more important. In closed communities, such as those in rural areas, participation in more organizations may improve bridging social capital. For the above reasons, older people in rural areas may benefit from participation in a greater number of organizations.

Many types of organizational participation were protective against functional decline in Model 1, which included factors such as age, equivalent income, educational attainment, marital status, and self-reported medical conditions. However, in Model 2, factors such as behavioral, psychosocial, and functional confounders, as well as participation in sports, hobbies, and work, were protective against incidences of decline.

This is the first longitudinal study to compare work with other community organizations by defining work as a type of social participation. Previous longitudinal studies focusing on the relationship between work and health outcomes among older people have examined work alone [20,36,37], and comparisons with other community organizations have been cross-sectional studies [38]. Given the current challenges posed by a rapidly declining birthrate and aging population, it is necessary to develop a social structure where many older people work [39]. Working support for older people is expected to contribute not only to a substantial increase in the labor force but also to a decrease in the number of older people requiring care [39]. This study showed that working support and improvement of working environment could be public health policies that would prevent the need for the provision of long-term care in rural and urban areas. In longitudinal studies of work and health outcomes [20,36,37], work is generally considered good for health. However, poor-quality work [36] is not good for health; therefore, additional analysis is necessary, since this research did not consider the type of work.

The results indicating that participation in sports and hobby groups were protective against disability were similar to previous studies [10]. According to this result, a good public health policy would include local government provision of regular opportunities for social participation in sports and hobbies in both rural and urban areas. Participation in sports and hobby groups has also been reported to prevent other poor health outcomes [16,18,19]. Previous studies have shown that older people in rural areas were unhealthier than older people in urban areas [20,24,29,30], but in this study, there was no difference in the incidence of functional disability between older people in rural and urban areas. The reason may be that there was no difference in the urban–rural participation rates in sports and hobby groups among the participants of this study. Even in rural areas, promoting

participation in groups such as sports and hobbies groups could prevent the incidence of functional decline. In Japan, the salon-type community intervention [40] has been implemented as one of the ways to promote social participation. These salons, managed by local volunteers, are held once or twice a month in communal spaces within walking distance of community members' homes, and older people can meet and interact with others through enjoyable, relaxing, and sometimes educational programs [40]. Moreover, participation in local community organizations was only protective against decline in rural older people in this study. In the scoping review by Carver et al. [41], older people who lived in rural areas had many opportunities to engage in community-association activities, and through such social participation, a sense of belonging was created. They suggested that such social participation is important for achieving successful aging in rural areas.

The preventive effects against functional decline of the number and types of social participation were almost the same among both rural and urban areas in this study. Quite a few studies on age-friendly cities showed that urban areas are suitable for active aging [42]. One of the reasons for that may be a larger quantity of amenities and possibilities for social interactions/organizations and easier access to those in urban areas compared to rural areas. It could be an effective intervention that older people move to urban areas when their health/physical ability starts to decline. Nowadays, the compact city, i.e., located in the rural city center, but short-distance from urban functions, trials have begun in Japan [43,44], and their effectiveness is expected to be verified.

This study has two strengths. First, this is the first study to target older people in many municipalities, including rural and urban areas, in contrast to previous studies that only focused on the number and type of organization in which older people participated [10,13,16–18]. Second, the data used in this study was collected over a long period (about six years) and excluded respondents receiving long-term care within two years, thereby removing the possibility of reverse causality (i.e., the possibility that people who had a high risk of functional decline did not participate socially).

This study had three limitations. First, we did not consider the frequency of social participation. It has been reported that the relationship between social participation and health outcomes differs depending on the frequency of social participation [16,18,38]. However, this research emphasized a comparison between rural and urban areas in line with a previous study [10]. Second, we did not consider the older people's role of the organization they participated in, such as being a member or a leader. A leading role in an organization has an additional effect on social participation and health outcomes [15,45]. Finally, this study only focuses on the differences between rural and urban areas; however, there may be other environmental characteristics to consider. The NuAge Study showed environmental factors associated with social participation of older people vary by living areas, such as metropolitan, urban, and rural areas [29]. In Japan, it was reported that environmental factors such as access to facilities, shops, and parks and sidewalks were related to participation in sports groups [46]. Future longitudinal or interventional studies focusing on rural and urban environmental improvement will be needed.

5. Conclusions

We compared the relationship between social participation, including work and incidence of functional decline in rural and urban older people, to inform public health policies that would prevent functional decline in older individuals residing in Japan. Participating in various organizations protected older people from functional decline, and, thus, it might be essential to facilitate the benefits of such participation to both rural and urban older people. Furthermore, participation in sports, hobbies, and work was protective against incidences of decline in both rural and urban regions. For both rural and urban older people, promoting social participation, such as sports and hobbies groups and employment support, seems to be an important aspect of public health policies that would prevent functional decline.

Supplementary Materials: The following are available online at http://www.mdpi.com/1660-4601/17/2/617/s1, Table S1: Complete case analysis: HRs for participation in one, two, and three or more different types of organizations, Table S2: The full modeling results for participation in one, two, and three or more different types of organizations in Model 2, Table S3: Complete case analysis: HRs for type of social participation (reference: nonparticipation in each organization), Table S4: The full modeling results for HRs for type of social participation (reference: nonparticipation in each organization).

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Wider Dental Care Coverage Associated with Lower Oral Health Inequalities: A Comparison Study between Japan and England

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Abstract: Countries with different oral health care systems may have different levels of oral health related inequalities. We compared the socioeconomic inequalities in oral health among older adults in Japan and England. We used the data for adults aged 65 years or over from Japan (N = 79,707) and England (N = 5115) and estimated absolute inequality (the Slope Index of Inequality, SII) and relative inequality (the Relative Index of Inequality, RII) for edentulism (the condition of having no natural teeth) by educational attainment and income. All analyses were adjusted for sex and age. Overall, 14% of the Japanese subjects and 21% of the English were edentulous. In both Japan and England, lower income and educational attainment were significantly associated with a higher risk of being edentulous. Education-based SII in Japan and England were 9.9% and 26.7%, respectively, and RII were 2.5 and 4.8, respectively. Income-based SII in Japan and England were 9.2% and 14.4%, respectively, and RII were 2.1 and 1.9, respectively. Social inequalities in edentulous individuals exist in both these high-income countries, but Japan, with wider coverage for dental care, had lower levels of inequality than England.

Keywords: international comparison; edentulism; oral health inequality; universal health coverage; slope index of inequality; relative index of inequality

1. Introduction

Health care systems are one of the structural social determinants of health inequalities [1]. There are substantial differences in the health care system between countries in terms of the coverage for health care across populations, for example, the target person, the scope of treatment available, the target disease and the copayment [2–4]. Universal health coverage has been promoted in the Millennium

Summit at the United Nations and World Health Organisation (WHO), and expanding oral care in universal health coverage is desired [5,6].

There are differences in oral health care coverage across countries. Japan and England have a similar universal health care system. However, the dental health care system was the difference between the two countries [7,8]. Japan has a public universal health care insurance system that includes most of dental treatments. As a result, Japan is one of the countries providing the most accessible dental care in the world from an international perspective. Japanese people attend dental care 3.2 times per year (reported in 2011), which is the most frequent dental attendance pattern among the Organisation for Economic Co-operation and Development (OECD) countries [9]. The percentage of Japanese household expenditure on dental services is 0.4% [10]. In England, some dental care is also covered by the public health care system, the National Health Service (NHS) [8]. In the United Kingdom (UK), dental care in the past year was 0.8 times per person (reported in 2011) [9], and the percentage of household expenditure on dental services was 12.0% [11]. These large differences in health care characteristics and coverage could affect the level of inequalities in oral health at the population level. In both Japan and England, there are inequalities in access to dental care [12–17]. Recently, universal health coverage is promoted in the world, and it is considered to decrease oral health inequalities [1]. However, few studies compared the degree of oral health inequalities between the countries with different coverages, and to the best of our knowledge, no international comparative study on oral health inequalities has included Japan, the country with one of the highest oral health care coverage.

The global burden of disease study reported the prevalent nature and large burden of severe tooth loss [18]. Edentulism (the condition of having no natural teeth) is the final form of severe tooth loss. Accumulation of the experiences of dental caries and periodontal disease through life-course cause edentulism [19,20]. Therefore, it is prevalent among the older population [21], and it can reflect oral health inequalities determined by a wider range of dental health care across the life-course. We hypothesised that inequalities in edentulism would be smaller in Japan with wider dental care coverage than in England. The objective of this study is to compare the association between socioeconomic status and edentulism among older adults in Japan and England.

2. Materials and Methods

2.1. Participants

We used cross-sectional data from the Japan Gerontological Evaluation Study (JAGES) [22] and the English Longitudinal Study of Ageing (ELSA) [23]. The JAGES and ELSA are both ongoing prospective cohort studies investigating social and behavioural factors associated with a functional decline or cognitive impairment among older individuals. The target population of the JAGES was 169,215 community-dwelling people aged 65 years and older selected from 31 municipalities in 12 prefectures in Japan from August 2010 to January 2012 (Wave 3). A total of 112,123 people participated in the JAGES (response rate = 66.3%). The ELSA data were collected between June 2010 and May 2011 (Wave 5) from a total of 10,274 community-dwelling people aged 50 years and older living in England. Those certified for long-term care in JAGES and those under the age of 65 years in ELSA were excluded. Then, both JAGES and ELSA data obtained from older adults aged over 65 years and older with valid responses (no missing data) in the variables included in this study were used for our analyses (Figure 1).

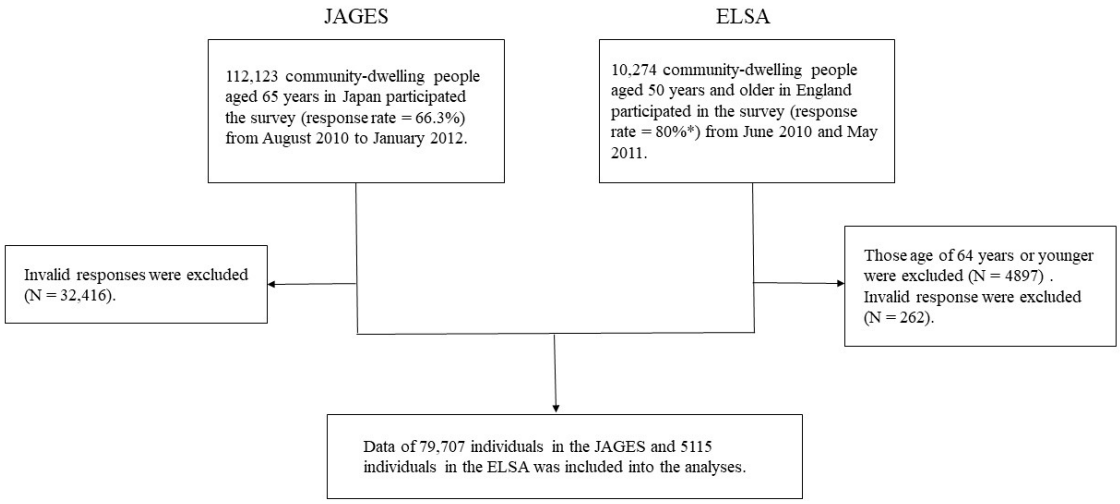

Figure 1. Flowchart of the selection of participants for the study (JAGES, Japan Gerontological Evaluation Study; ELSA, English Longitudinal Study of Ageing). * This response rate was taken from cohort profile of ELSA [23].

2.2. Ethical Considerations

Ethical approval for the study was obtained from the Ethics Committee at Nihon Fukushi University, Japan (Approval number: 10–05). ELSA was approved by the South Central Berkshire Research Ethics Committee through an application to the National Research Ethics Service [24].

2.3. Dependent Variable

The dependent variable for the present analysis was edentulism (= "Has no teeth"). The JAGES self-report questionnaire on the current dental status of the participants used the following question: "How many natural teeth do you presently have?" There were four choices: (1) I have 20 or more natural teeth, (2) I have 10 to 19 natural teeth, (3) I have 1 to 9 natural teeth, or (4) I have no natural teeth. We categorised the answers as "dentate" (1–3) and answer "edentulous" (4). In the ELSA, the question was as follows: "In relation to your dental health, which of the following applies to you?" There were four choices: (1) Has no natural teeth and wears dentures, (2) Has both natural teeth and denture(s), (3) Has only natural teeth, or (4) Has neither natural teeth nor dentures. We categorised the answers as "dentate" (2 and 3) and "edentulous" (1 and 4).

2.4. Explanatory Variables

We used equivalised annual income and educational attainment as indicators of participants' socioeconomic status. Income levels were classified as follows: lowest, low, middle and high (JAGES: ≤12,500, 12,501–19,445, 19,446–30,619, ≥30,620 (USD, 1 USD = 100 JPY), ELSA: ≤11,911, 11,912–<16,459, 16,459–<23,810, >=23,810 (USD, 1 USD = 0.8 GBP), respectively). For educational attainment, we acknowledge that possible country differences in the education system between Japan and England. We consulted with the ELSA data management team and harmonised the education level between the two countries (ELSA 3 and 4 Label = JAGES 1 and 2 (15 years or younger), ELSA 5, 6 and 7 Label = JAGES 3 (16–18 years) and ELSA 8 Label = JAGES 4 (19 or older)). The samples were categorised according to the age at which they completed their formal education as low (15 years or younger), middle (16–18 years) and high (19 years or older) for both the JAGES and ELSA. Age (65–69, 70–74, 75–79, 80–84 and ≥85 years) and sex (men and women) were used as covariates.

2.5. Data Analyses

Firstly, we described the demographic characteristics of the participants. For the participants' age, we used the median and first quartile–third quartile because our data were not distributed normally (Kolmogorov–Smirnov test, $p < 0.001$). Secondly, to show the sex- and age-adjusted association of socioeconomic status on edentulism, sex- and age-adjusted prevalence ratios were calculated from Poisson regression analyses. Finally, we estimated the Slope Index of Inequality (SII) and the Relative Index of Inequality (RII) to evaluate absolute and relative inequalities [25] in edentulism. SII referents the absolute difference in a health indicator between those with a higher and those with a lower level of socioeconomic status. RII is a relative measure of inequality that indicates the ratio of health status between the higher and lower levels of socioeconomic status groups. Both indicators were calculated using regression-based methods [26]. To determine the explanatory factors in the association between socioeconomic status (income and educational attainment) and edentulism, we built the models for each country as follows. Model 1 tested the association between a socioeconomic status variable (income or educational attainment) and edentulism (univariate model). Model 2 examined the association between a socioeconomic status variable (incomes or educational attainment) and edentulism after adjusting for age and sex (age and sex adjusted model). All analyses were done by Stata MP version 14 [26].

3. Results

We used the data obtained from 79,707 individuals in the JAGES and 5115 individuals in the ELSA Wave that had no missing responses. There were 49.6% men in the JAGES and 45.6% men in the ELSA. The median (first quartile–third quartile) age was 73.0 (69.0–77.0) years for JAGES and 73.0 (69.0–79.0) years for ELSA. The prevalence of edentulism was 13.8% for JAGES and 20.6% for ELSA.

Table 1 shows the prevalence of sociodemographic attributes according to the dental status from JAGES and ELSA. Women had a higher proportion of edentulism than men, especially in ELSA. Social gradients in dental status were observed in both samples, and participants with higher education or income had lower percentages of edentulism.

Table 1. Descriptive distribution of edentulous participants in Japan and England.

		Total	JAGES (*N* = 79,707)		Total	ELSA (*N* = 5115)	
			N	%		*N*	%
Age							
	65–69 year old	24,567	1331	5.4%	1537	172	11.2%
	70–74 year old	23,911	2322	9.7%	1411	244	17.3%
	75–79 year old	17,152	2904	16.9%	1029	239	23.2%
	80–84 year old	9506	2586	27.2%	640	190	29.7%
	85+ year old	4571	1881	41.2%	498	209	42.0%
Sex							
	Men	39,568	5491	13.9%	2334	417	17.9%
	Women	40,139	5533	13.8%	2781	637	22.9%
Income							
	Lowest	21,076	4513	21.4%	1278	356	27.9%
	Low	19,455	2386	12.3%	1280	322	25.2%
	Middle	18,916	2058	10.9%	1279	247	19.3%
	High	20,260	2067	10.2%	1278	129	10.1%
Educational attainment							
	Low	36,085	1934	21.0%	2815	779	27.7%
	Middle	28,603	714	10.5%	1645	233	14.2%
	High	15,019	297	8.2%	655	42	6.4%

JAGES, Japan Gerontological Evaluation Study; ELSA, English Longitudinal Study of Ageing.

Figures 2 and 3 show the association between edentulism and socioeconomic status in Japan and England. In both Japan and England, lower income and lower educational attainment were significantly and independently associated with both higher risk of edentulism (excluding the middle income of Japan, $p < 0.001$). Income and educational attainment gradient were appeared to be greater in England than in Japan in edentulism.

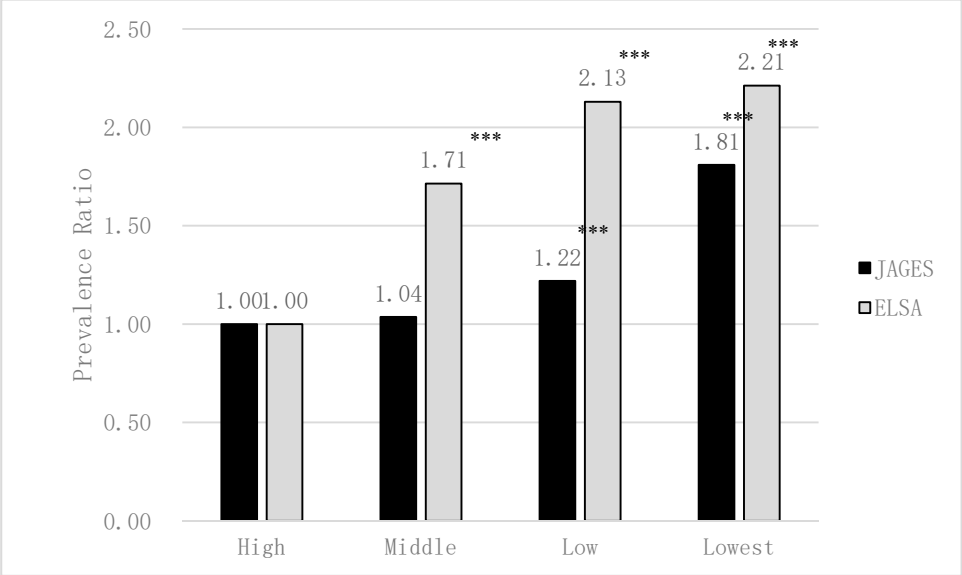

Figure 2. The association between edentulism and equivalised annual income in Japan and England estimated by Poisson regression analyses (adjusted for sex and age; JAGES N = 79,707, ELSA N = 5115). *** $p < 0.001$.

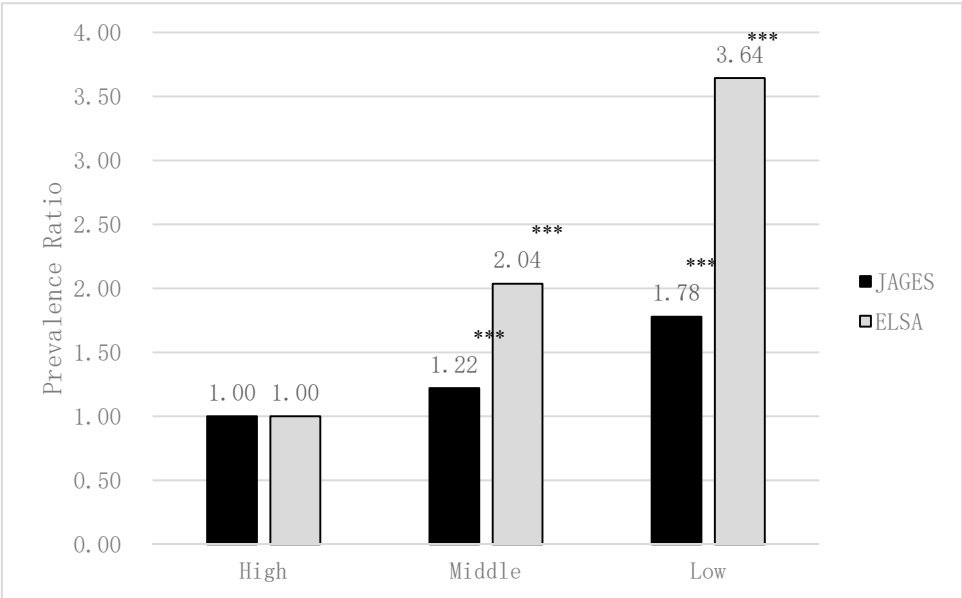

Figure 3. The association between edentulism and educational attainment in Japan and England estimated by Poisson regression analyses (adjusted for sex and age; JAGES N = 79,707, ELSA N = 5115). *** $p < 0.001$.

Table 2 shows the SII and RII of edentulism in Japan and England. The absolute socioeconomic difference in edentulism between groups with the lowest and highest income (SII for income) was 11.8% (95% CI, 11.0; 12.0) for JAGES and 18.5% (95% CI, 15.0; 21.9) for ELSA (univariate models). After adjusting for age and sex, significant absolute income differences in edentulism for both JAGES

and ELSA (JAGES = 9.2% (95% CI, 8.6; 9.9) and ELSA = 14.4% (95% CI, 11.0; 17.7)) remained. The relative income differences in edentulism (RII for income) were also significant after adjustment for age and sex for both JAGES and ELSA (JAGES = 2.1 (95% CI, 2.0; 2.2) and ELSA = 1.9 (95% CI, 1.6; 2.3)).

Table 2. Absolute and relative socioeconomic inequalities of edentulousness in JAGES and ELSA.

		JAGES (*N* = 79,707)		ELSA (*N* = 5115)	
		Univariate Model	Age and Sex Adjusted Model	Univariate Model	Age and Sex Adjusted Model
Income	SII (%) (95% CI)	11.77 (11.04; 12.50)	9.24 (8.58; 9.90)	18.46 (15.02; 21.90)	14.35 (10.97; 17.73)
	RII (95% CI)	2.47 (2.34; 2.61)	2.07 (1.96; 2.18)	2.40 (2.03; 2.83)	1.92 (1.63; 2.27)
Educational attainment	SII (%) (95% CI)	15.00 (14.18; 15.83)	9.93 (9.19; 10.68)	31.93 (28.22; 35.64)	26.65 (23.11; 30.20)
	RII (95% CI)	3.36 (3.13; 3.61)	2.45 (2.29; 2.63)	5.88 (4.55; 7.61)	4.79 (3.70; 6.19)

SII, Slope Index of Inequality; RII, Relative Index of Inequality.

For education-based inequalities, the absolute difference in edentulism between groups with the lowest and highest educational attainment (SII for education) was 15.0% (95% CI, 14.2; 15.8) for JAGES and 31.9% (95% CI, 28.2; 35.6) for ELSA. Even after adjusting for age and sex, significant absolute educational attainment differences in edentulism for both JAGES and ELSA (JAGES = 9.9% (95% CI, 9.2; 10.7) and ELSA = 26.7% (95% CI, 23.1; 30.2)) were observed. The relative educational attainment differences in edentulism (RII for education) were also significant after adjustment for age and sex for both studies (JAGES = 2.5 (95% CI, 2.3; 2.6) and ELSA = 4.8 (95% CI, 3.7; 6.2)).

Overall, absolute oral health inequalities were smaller in Japan than in England. Education appears to play a crucial role in determining oral health inequalities compared to income, particularly in England.

4. Discussion

The present study reports both absolute and relative socioeconomic (income and education) inequalities in edentulism in Japan and England. In general, oral health inequalities were smaller in Japan, a country with one of the highest levels of public coverage for dental care, compared to England. The prevalence of edentulism was higher in England than in Japan. Socioeconomic inequalities, especially educational inequalities, were relatively larger in England than in Japan, and the differences between the two countries were most obvious.

For oral health inequalities, our results were consistent with previous studies. Japanese national health data showed that lower educational attainment and lower equivalent household expenditure were associated with fewer remaining teeth [27], while lower income was associated with poor dental status in Japanese older people [28]. Similarly, socioeconomic inequalities, number of remaining teeth [29], edentulism [30], dental caries [31,32] and periodontal disease [33,34] were reported in the UK. Using large cohort data with harmonised measures, our findings of oral health inequalities determined by income and education offer extended support to previous studies.

Differences in accessibility to dental care could explain the present results of smaller oral health inequalities in Japan than in England. Inequalities in access to dental care are also reported in both countries [16,35]. However, in the UK, out-of-pocket expenses for dental care were higher, and the frequency of dental visits was lower than in Japan [9–11]. In England, previous studies showed that almost 20% of the participants tried to get an NHS dental appointment, but failed to get one within a reasonable time [36,37]. People unable to book an NHS dental appointment had to visit a costly private dentist instead. On the other hand, the Japanese insurance system provides a free access system to dental care, allowing the Japanese to select any medical institution where they can receive high-quality medical and dental services at a low cost [38]. Moreover, Japan has a life-course oral health care system [7]. This system is provided as part of general health services, and the programme is based on health legislation. For preschool children, a national programme that includes physical,

medical and dental examinations is conducted for all 18-month-olds and 3-year-olds. After the dental examination, dental hygienists provide maternal and child oral health education. For school children, every public primary, junior and senior high school has a school dentist. The school dentist performs dental examination for the school children at least once a year. Moreover, all schools incorporate oral health education into their curriculum. These systems are believed to be associated with low oral health inequality in Japan.

The United Nations and WHO promote universal health coverage [5,39]. Our findings suggest the possibility that more comprehensive dental care coverage reduces oral health inequalities. A wider inclusion of dental care in universal health coverage is required to improve oral health and reduce oral health inequalities. Notably, even in Japan, there are still significant levels of oral health inequalities, suggesting room for improvement, such as a wide range of oral health promotion in the context of social determinants of health [6,40].

Our study had several limitations and strengths. First, our study used a cross-sectional design, and hence, we could not establish a causal relationship between socioeconomic indicators and edentulism. Second, the measurements were obtained from a self-administered questionnaire. However, clinical assessment of remaining teeth is more accurate than self-administered questionnaires. Still, the validity of the self-reported number of remaining teeth was verified [31]. Finally, potential biases could be likely due to fewer cases. However, the strength of this study was that it used large cohort data from each country with harmonised measures, offering the level of oral health inequalities in both absolute and relative terms that were comparable.

5. Conclusions

Both absolute and relative inequalities in edentulism were found in Japan and England. Most of the inequality measurements suggested that oral health inequalities were smaller in Japan, a country with one of the highest levels of public coverage for dental care in the world.

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Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

CI	Confidence Interval
ELSA	English Longitudinal Study of Ageing
OECD	Organisation for Economic Co-operation and Development
JAGES	Japan Gerontological Evaluation Study
NHS	National Health Service
RII	Relative Index of Inequality
UK	United Kingdom
SII	Slope Index of Inequality
WHO	World Health Organisation

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ORIGINAL ARTICLE

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Size of company of the longest-held job and mortality in older Japanese adults: A 6-year follow-up study from the Japan Gerontological Evaluation Study

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Abstract

Objectives: Very few longitudinal studies have investigated the question of whether differences in company size may give rise to health inequalities. The aim of this study was to examine the relationship between company size of the longest-held job and mortality in older Japanese adults.

Methods: This study used longitudinal data from the Japan Gerontological Evaluation Study. Surveys were sent to functionally independent individuals aged 65 or older who were randomly sampled from 13 municipalities in Japan. Respondents were followed for a maximum of 6.6 years. The Cox proportional hazards model was used to calculate mortality hazard ratios (HRs) for men and for women. Analysis was carried out on 35 418 participants (197 514 person-years).

Results: A total of 3935 deaths occurred during the 6-year follow-up period. Among men, in Model 1 that adjusted for age, educational attainment, type of longest-held job, and municipalities, mortality HRs decreased significantly with increasing size of company (P for trend = .002). Compared to companies with 1-9 employees, the mortality HR (0.78, 95% confidence interval: 0.68-0.90) was significantly lower for companies with 10 000 or more employees. However, there were no significant differences among women (P for trend = .41).

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Conclusions: In men, mortality in old age may decrease with increasing size of company of the longest-held job. To reduce health inequalities in old age due to differences in size of company, studies should be conducted to determine the underlying mechanisms and moderating factors and those findings should be reflected in labor policies and occupational health systems.

KEYWORDS

health status disparities, Japan, mortality, occupational health

1 | INTRODUCTION

After the Second World War, Japan became one of the healthiest countries in the world through its universal health insurance system and equal access to opportunities for education and medical care and has reduced health inequalities since.[1] In recent years, however, health inequalities are trending upwards as the socioeconomic gap widens.[1,2] Size of company could be one factor associated with health inequalities under the scope of occupation.

In Japan, the Industrial Safety and Health Act requires health supervisors and occupational health physicians to be appointed to workplaces with 50 employees or more but not to workplaces with less than 50 employees.[3] As a result, smaller workplaces have lower quality industrial health and safety activities.[4,5] They may also offer lower salaries on average.[6] Considering life course,[7] these differences due to company size may lead to health inequalities in the future. The average length of employment is particularly long among Japanese male workers compared to other workers in other countries,[8] and determining whether differences in longest-held job with company size are leading to health inequalities in Japan could provide useful information.

In the working generation, previous cross-sectional studies have found a lower frequency of current smokers,[9] daily drinkers,[9] problem drinkers,[10] health examination non-participation,[11] cancer screening non-participation,[12] and abnormalities in various health check-ups items (eg, blood pressure and blood sugar),[9] and lower scores for depressive symptoms[13] among workers in large companies than workers in small- and medium-sized companies. Nevertheless, few studies have examined whether such health disparities due to differences in size of company carry over into old age.

In a previous cohort study on older adults in Japan, men who had been working at workplaces with 49 or fewer employees as the longest-held job were reported to have a higher risk of poor instrumental activities of daily living (IADL) in old age than men at workplaces with 50 or more employees.[14] In that study, IADL was examined but mortality was not, leaving the question of whether size of company of the longest-held job is associated with mortality risk in old age unanswered. In addition, workplace size was only dichotomized into 50 or more and less than 50 employees in the study mentioned above, and therefore the dose-response relationship is unclear.

To test the hypothesis that mortality risk decreases with increasing company size, we examine the relationship between size of company of the longest-held job and mortality risk in older adults in Japan.

2 | MATERIALS AND METHODS

2.1 | Study design and participants

This study was a population-based prospective cohort study conducted in Japan. It was based on a sample from the Japan Gerontological Evaluation Study (JAGES) carried out in 13 municipalities ranging geographically from Hokkaido in northernmost Japan to the Kyushu region in southernmost Japan from August 2010 to January 2012. JAGES is a population-based gerontological survey aimed at clarifying the social determinants of health.[15] The survey was sent to 95 827 individuals aged 65 or older who were not certificated for needed long-term care at baseline. Certification of needed long-term care is based on evaluation of the need for long-term care according to uniform criteria for all of Japan,[16] and municipalities maintain records on who has been certified. Participants were selected at random sampling in each municipality. Among participants who responded to the baseline survey, those with invalid responses for ID number, age, and/or sex were excluded. Participants were followed for a maximum of 2416 days (6.6 years) and those with missing values for company size of the longest-held job, or who responded "I don't know" or "I have never had a job" to the question about company size and/or type of longest-held job were also excluded. Agriculture/forestry/fishery workers were additionally excluded as their longest-held job was often self-employment.[17,18]

2.2 | Measures

2.2.1 | Mortality outcome

We retrieved death records from 2010 to 2016 (maximum: 6.6 years) from the government database of public long-term care insurance.

2.2.2 | Size of company of the longest-held job

To determine the size of company of their longest-held job, an indicator was developed based on the comprehensive Japanese General Social Surveys[19] carried out in Japan. Participants were asked, "Of all of your jobs to date, about how many people worked in the entire company or organization where you were employed the longest?" Choices were 1-9 employees, 10-49 employees, 50-499 employees, 500-9999 employees, 10 000 employees or more, "I don't know," and "I have never had a job."

2.2.3 | Covariates

Based on previous studies,[14,20-22] age (65-69, 70-74, 75-79, 80, or 85 years or more), educational attainment (less than 9, 10-12 years, or more than 12 years), type of longest-held job (white-collar: professional/technical or administrative, pink-collar: clerical or sales/service, blue-collar: skilled/labor, or other[15]), and municipalities were used as covariates.

To investigate the contribution of behavioral factors to the relationship between size of company of the longest-held job and mortality, daily walking time (less than 30, 30-59, or 60 minutes or more), frequency of fruit and vegetable consumption (less than once a day, once a day, or twice a day or more), alcohol consumption status (current drinker, past drinker, or non-drinker), smoking status (never a smoker, past smoker, or current smoker), and frequency of health checkups (within 1 year, more than 2 years ago, or never) were used as mediators.

To investigate the role of illness in the relationship between size of company and mortality, self-reported medical condition for three major diseases (cancer, heart disease, and stroke) in old age were used as mediators.

To examine other income-mediated pathways, annual equivalized income (less than 2 million yen per year = low, 2-3.99 million yen per year = middle, 4 million yen or more per year = high) in old age was used as one mediator. Annual equivalized income was calculated by dividing gross household income by the square root of the number of household members.

2.3 | Statistics analysis

The Cox proportional hazards model was used to calculate mortality hazard ratios (HRs) for men and for women. Respondents who were lost to follow-up because they moved were excluded. In each model, size of company of 1-9 employees was set as the referent category. In Model 1, we adjusted for age, educational attainment, type of longest-held job, and municipalities. To investigate the contribution of behavioral factors in the relationship between size of company of the longest-held job and mortality, in Model 2, we adjusted for all the factors in Model 1 as well as walking time, frequency of fruit and vegetable consumption, alcohol consumption status, smoking status, and frequency of health checkups in old age. In Model 3, we adjusted for all the factors in Model 1 as well as self-reported medical condition for three major diseases in old age. In Model 4, we adjusted for all the factors in Model 1 as well as annual equivalized income in old age. As type of job is strongly associated with size of company,[23] we conducted stratified analysis by type of longest-held job.

Dummy variables were set for all variables. Based on a previous study, [24] a "missing" category was used in the analysis to account for missing responses. Test of linear trends in mortality rates were conducted using ordinary scaling across categories of size of company of the longest-held job. The threshold for significance was $P < .05$. All statistical analyses were conducted using IBM SPSS version 21.0.

3 | RESULTS

Responses were received from 62 426 of the 95 827 individuals who were sent the questionnaire (response rate: 65.1%; Figure 1). Of these, 5739 were excluded for having an invalid response for ID number, age, and/or sex and 2148 because they could not be successfully linked to death records, leaving 54 539 valid respondents (25 146 men and 29 393 women). The job category of the longest-held job was "agriculture/forestry/fishery workers" for 2608 men (2546 women) and never worked for 209 men (2764 women). After those who did not meet the required criteria (whose company size was unknown or missing, who never worked, or who were agriculture/forestry/fishery workers), the remainder was 35 418 participants who were used in the analysis. Participants were 19 260 men (54.4%) with a mean age of 73.3 ± 5.7 years and 16 158 women (45.6%) with a mean age of 72.9 ± 5.7 years.

The mean duration of follow-up was 5.5 ± 1.3 years for men and 5.7 ± 1.0 years for women. During the follow-up period, 2870 men (14.9%) and 1065 women (6.6%) died. The mortality rate per 1000 people was 27.2 for men and 11.6 for women.

Tables 1 and 2 show the characteristics of individuals by size of company of the longest-held job for men and women. For men, the size of company of the longest-held job was 1-9 employees for 17.0% of men, 10-49 employees for 21.9%, 50-499 employees for 27.4%, 500-9999 employees for 21.0%, and 10 000 or more employees for 12.6% (Table 1). For women, the size of company of the longest-held job was 1-9 employees for 25.9% of women, 10-49 employees for 32.5%, 50-499 employees for 27.8%, 500-9999 employees for 9.9%, and 10 000 or more employees for 3.9% (Table 2).

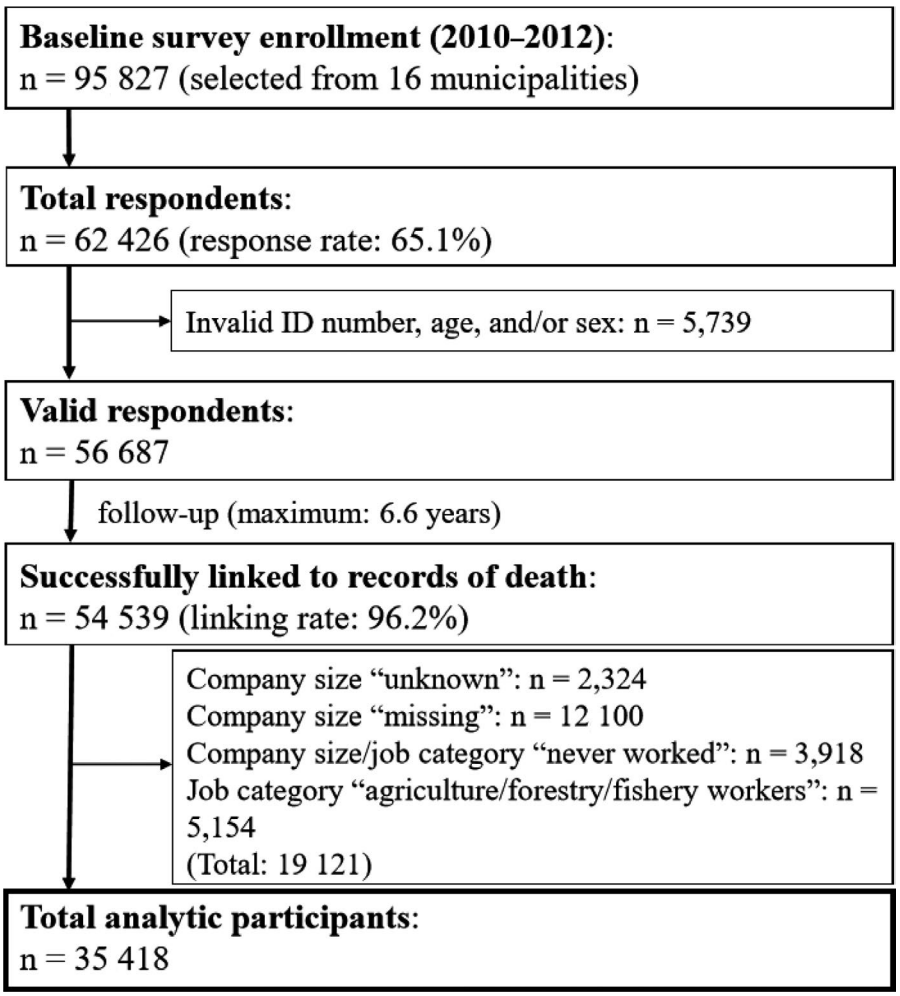

FIGURE 1 Flowchart of participants

Tables 3 and 4 show the mortality HRs for the size of company of the longest-held job. Among men, in a trend test, mortality HR decreased significantly with increasing size of company in Model 1 that adjusted for age, educational attainment, type of longest-held job, and municipalities ($P = .002$) (Table 3). In this model, only a company size of 10 000 employees or more had a significantly lower HR than a company size of 1-9 employees. In Model 2 that also adjusted for behavioral factors in old age, the trend became marginal ($P = .051$). In addition, the HRs for company size of at least 50 employees all approached 1. In Model 3 that adjusted for self-reported medical condition for three major diseases in old age in addition to the conditions in Model 1, the HRs did not differ significantly from those in Model 1. In Model 4 that adjusted for annual equivalized income in old age in addition to the conditions in Model 1, the HRs for company size of 500 employees or more all approached 1 but the changes in HR were smaller than Model 2. Among women, there were no significant associations in any of the models (Table 4).

In stratified analysis by type of longest-held job, no significant associations were observed in any of the models among male while-collar workers (Table 3). In Model 1, the HR was significantly lower for a company size of 10 000 employees or more compared to a company size of 1-9 employees for male pink-collar, blue-collar, and other workers. Among women, there were no associations between size of company and mortality (Table 4). Appendix S1 shows the mortality HR for the longest-held job. Among men, the HR was significantly higher only for other workers compared to white-collar workers. Among women, there were no associations between the longest-held job and mortality.

4 | DISCUSSION

In the present study, we investigated the relationship between size of company of the longest-held job and mortality in older Japanese adults using a large cohort study. The results showed that, among men, mortality rate decreases as size of company of the longest-held job increases. In addition, the mortality HR was lower in companies with 10 000 or more employees compared to companies with 1-9 employees. No such associations were found for women.

TABLE 1 Individual characteristics of men according to size of company of the longest-held job

	Size of company of the longest-held job (number of employees)											
	1-9		10-49		50-499		500-9999		10 000+		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Total	3274	100.0	4213	100.0	5285	100.0	4053	100.0	2435	100.0	19 260	100.0
Age												
Mean ± SD	73.3 ± 5.6		73.4 ± 5.7		73.2 ± 6.7		73.0 ± 5.6		73.5 ± 5.9		73.3 ± 5.7	
Educational attainment												
Less than 6 y	64	2.0	64	1.5	56	1.1	27	0.7	10	0.4	221	1.1
6-9 y	1750	53.5	1941	46.1	2074	39.2	1110	27.4	582	23.9	7457	38.7
10-12 y	942	28.8	1178	28.0	1862	35.2	1503	37.1	1012	41.6	6497	33.7
13 y or more	472	14.4	961	22.8	1224	23.2	1354	33.4	806	33.1	4817	25.0
Type of longest-held job												
White-collar	1020	31.2	1484	35.2	1897	35.9	1751	43.2	1169	48.0	7321	38.0
Pink-collar	910	27.8	924	21.9	1459	27.6	983	24.3	627	25.7	4903	25.5
Blue-collar	636	19.4	926	22.0	1116	21.1	880	21.7	411	16.9	3969	20.6
Other	487	14.9	580	13.8	487	9.2	216	5.3	129	5.3	1899	9.9
Walking time												
Less than 30 min	1101	33.6	1353	32.1	1639	31.0	1107	27.3	591	24.3	5791	30.1
30-59 min	931	28.4	1326	31.5	1832	34.7	1418	35.0	911	37.4	6418	33.3
60 min or longer	1077	32.9	1334	31.7	1610	30.5	1334	32.9	842	34.6	6197	32.2
Frequency of fruit and vegetable consumption												
Less than once a day	836	25.5	1126	26.7	1339	25.3	837	20.7	443	18.2	4581	23.8
Once a day	1108	33.8	1445	34.3	1832	34.7	1396	34.4	783	32.2	6564	34.1
Twice or more a day	1137	34.7	1427	33.9	1847	34.9	1595	39.4	1078	44.4	7084	36.8
Alcohol consumption status												
Current drinker	1704	52.0	2181	51.8	2862	54.2	2307	56.9	1444	59.3	10 498	54.5
Past drinker	202	6.2	267	6.3	348	6.6	247	6.1	128	5.3	1192	6.2
Non-drinker	1174	35.9	1543	36.6	1813	34.3	1258	31.0	729	29.9	6517	33.8
Smoking status												
Has never smoked	790	24.1	939	22.3	1184	22.4	851	21.0	533	21.9	4297	22.3
Past smoker	1583	48.4	2070	49.1	2740	51.8	2263	55.8	1372	56.3	10 028	52.1
Current smoker	654	20.0	902	21.4	1023	19.4	689	17.0	382	15.7	3650	19.0
Health checkups												
Within 1 y	1678	51.3	2342	55.6	3183	60.2	2498	61.6	1524	62.6	11 225	58.3
2+ y ago	797	24.3	1049	24.9	1277	24.2	1059	26.1	654	26.9	4836	25.1
Never	650	19.9	669	15.9	658	12.5	412	10.2	202	8.3	2591	13.5

(Continues)

TABLE 1 (Continued)

	Size of company of the longest-held job (number of employees)											
	1-9		10-49		50-499		500-9999		10 000+		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Self-reported medical condition												
Cancer	192	5.9	243	5.8	338	6.4	258	6.4	162	6.7	1193	6.2
Heart disease	476	14.5	633	15.0	784	14.8	578	14.3	347	14.3	2818	14.6
Stroke	68	2.1	93	2.2	87	1.6	77	1.9	51	2.1	376	2.0
Annual equivalized income												
Low	1580	48.3	1920	45.6	2184	41.3	1302	32.1	647	26.6	7633	39.6
Middle	952	29.1	1352	32.1	2003	37.9	1967	48.5	1296	53.2	7570	39.3
High	329	10.0	430	10.2	522	9.9	470	11.6	320	13.1	2071	10.8

Note: Missing values for each factor have been omitted.

Mortality is one comprehensive health outcome, and we discovered the novel finding that mortality is indeed associated with company size. Several previous studies have found lower risks of health outcomes (abnormalities in various health check-ups items,[9] depressive symptoms,[13] and decline in IADL[14]) in larger companies compared to smaller companies. However, only a few longitudinal studies have examined this relationship. In addition, as we know, no previous research has examined the relationship with mortality. In the present study, our hypothesis that mortality risk would decrease with increasing size of company of the longest-held job was supported only in men. A previous cross-sectional study did not find consistently positive associations with increasing company size for psychological distress.[25] This finding and our results suggest that there may be different associations with company size depending on cause-specific mortality. In the present study, we were only able to examine all-cause mortality, and further studies are needed to clarify this point.

Among women, on the other hand, there was no association between size of company and mortality. Similarly, in a previous cohort study, workplace size was associated with IADL decline in men but not in women.[14] The results of our study were consistent with the results of that study. Many unmarried women began working full time after Second World War, but most eventually quit for marriage or to have and raise children, and they often chose part-time work after their children were grown.[26] This may be why the health-related effects of working at a company are weaker compared to men.

Income, occupational hazards, lifestyle, occupational health services, job stress, social capital, social security/pension, and other factors have been identified as possible mechanisms for health inequalities in the scope of occupation.[20] These factors may also contribute to differences in mortality with size of company of the longest-held job. To examine the contribution of behavioral factors in old age to the relationship between size of company of the longest-held job and mortality, we additionally adjusted for behavioral factors in old age in Model 2. Among men, of the health behaviors we examined, there tended to be a lower prevalence of unhealthy behaviors (walking less than 30 minutes per a day, eating fruits and vegetables less than once a week, current smoker, and not receiving health checkups) as the size of company increased. This trend has also been observed in previous studies.[9,11] Differences in the work environment (eg, industrial health and safety activities) in the past may be reflected in health behaviors that persist into old age. In Model 2, the significance disappeared and the HRs for men who had been working in a company with at least 50 employees as the longest-held job were closer to 1 (50-499: 0.94 [0.84-1.05], 500-9999: 0.97 [0.86-1.09], and 10 000−: 0.84 [0.72-0.97]) compared to the HRs in Model 1 (0.92 [0.83-1.03], 0.93 [0.82-1.05], and 0.78 [0.68-0.90], respectively). This suggests that behavioral factors in old age may help shrink differences in mortality risk.

To examine the contribution of diseases and income in old age, we additionally adjusted for three major diseases in old age in Model 3, and annual equivalized income in old age in Model 4. Almost no changes in HRs were observed in Model 3, suggesting that prevalence of the diseases did not increase proportionately with size of company; the largest difference in prevalence of the three major diseases with difference in size of company was 0.9% for men (cancer: between 5.8% for 10-49 employees and 6.7% for 10 000 or more employees). The percentage of participants receiving a health checkup within 1 year increased with increasing size of company, with a difference as high as 11.3% (1-9 employees: 51.3%, 10 000 or more employees: 62.6%). The higher rate of having health

TABLE 2 Individual characteristics of women according to size of company of the longest-held job

	Size of company of the longest-held job (number of employees)											
	1-9		10-49		50-499		500-9999		10 000+		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Total	4177	100.0	5252	100.0	4492	100.0	1605	100.0	632	100.0	16 158	100.0
Age												
Mean ± SD	73.2 ± 5.8		73.2 ± 5.8		72.6 ± 5.5		72.1 ± 5.3		73.1 ± 5.6		72.9 ± 5.7	
Educational attainment												
Less than 6 y	112	2.7	125	2.4	83	1.8	20	1.2	0	0.0	340	2.1
6-9 y	2019	48.3	2518	47.9	2032	45.2	599	37.3	175	27.7	7343	45.4
10-12 y	1488	35.6	1763	33.6	1705	38.0	714	44.5	306	48.4	5976	37.0
13 y or more	481	11.5	752	14.3	587	13.1	255	15.9	141	22.3	2216	13.7
Type of longest-held job												
White-collar	516	12.4	732	13.9	627	14.0	188	11.7	80	12.7	2143	13.3
Pink-collar	2109	50.5	2233	42.5	2028	45.1	910	56.7	418	66.1	7698	47.6
Blue-collar	329	7.9	615	11.7	686	15.3	216	13.5	41	6.5	1887	11.7
Other	834	20.0	1111	21.2	762	17.0	180	11.2	50	7.9	2937	18.2
Walking time												
Less than 30 min	1413	33.8	1645	31.3	1311	29.2	444	27.7	163	25.8	4976	30.8
30-59 min	1283	30.7	1812	34.5	1586	35.3	575	35.8	225	35.6	5481	33.9
60 min or longer	1240	29.7	1513	28.8	1349	30.0	496	30.9	201	31.8	4799	29.7
Frequency of fruit and vegetable consumption												
Less than once a day	635	15.2	878	16.7	649	14.4	183	11.1	54	8.5	2399	14.8
Once a day	1277	30.6	1540	29.3	1269	28.3	393	24.5	139	22.0	4618	28.6
Twice or more a day	2057	49.2	2585	49.2	2364	52.6	950	59.2	408	64.6	8364	51.8
Alcohol consumption status												
Current drinker	626	15.0	825	15.7	763	17.0	289	18.0	131	20.7	2634	16.3
Past drinker	37	0.9	58	1.1	50	1.1	20	1.2	12	1.9	177	1.1
Non-drinker	3298	79.0	4091	77.9	3450	76.8	1207	75.2	456	72.2	12 502	77.4
Smoking status												
Has never smoked	3361	80.5	4249	80.9	3623	80.7	1326	82.6	522	82.6	13 081	81.0
Past smoker	239	5.7	283	5.4	247	5.5	88	5.5	40	6.3	897	5.6
Current smoker	149	3.6	195	3.7	194	4.3	49	3.1	21	3.3	608	3.8

(Continues)

TABLE 2 (Continued)

	Size of company of the longest-held job (number of employees)											
	1-9		10-49		50-499		500-9999		10 000+		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Health checkups												
Within 1 y	2324	55.6	3104	59.1	2719	60.5	1003	62.5	417	66.0	9567	59.2
2+ y ago	912	21.8	1112	21.2	1000	22.3	352	21.9	138	21.8	3514	21.7
Never	780	18.7	787	15.0	588	13.1	175	10.9	57	9.0	2387	14.8
Self-reported medical condition												
Cancer	131	3.1	157	3.0	122	2.7	43	2.7	27	4.3	480	3.0
Heart disease	375	9.0	460	8.8	385	8.6	140	8.7	62	9.8	1422	8.8
Stroke	30	0.7	38	0.7	18	0.4	8	0.5	3	0.5	97	0.6
Annual equivalized income												
Low	1794	42.9	2226	42.4	1868	41.6	568	35.4	145	22.9	6601	40.9
Middle	1159	27.7	1616	30.8	1489	33.1	659	41.1	322	50.9	5245	32.5
High	467	11.2	448	8.5	402	8.9	164	10.2	95	15.0	1576	9.8

Note: Missing values for each factor have been omitted.

checkups at larger companies may have resulted in earlier detection of the three major diseases. This may be why presence of the three diseases alone could not explain the association between size of company and mortality.

In the model that adjusted for annual equivalized income, we observed similar, although smaller, changes in HRs as the model that adjusted for behavioral factors. Income may be particularly relevant, as salary tends to decrease with decreasing company size.[6] In the present study as well, the ratio of participants with a lower annual equivalized income increased with decreasing size of company. In addition, a systematic review indicated that lower income is associated with a higher all-cause mortality rate.[27] This could explain why income contributes to the relationship between size of company and mortality.

Examinations of the pathways for these three factors suggest that health behaviors and annual equivalized income in old age may play a role in the relationship between size of company and mortality. One possible reason why HRs were only significantly lower in companies with 10 000 or more compared to companies with 1-9 employees may be that differences in health behaviors are the strongest of the three factors. Further research is needed to clearly verify the indirect effects mediating behavioral factors, diseases, and income.

In analysis stratified by type of longest-held job, there were no significant differences in the relationship between size of company and mortality among male white-collar workers. Previous studies have examined how health outcomes are related to either company size or different types of jobs separately. Previous cohort studies that examined the relationship between type of job and health outcomes in Japanese people did not find any associations with decline of IADL[14] or all-cause mortality[21] in either men and women. To our knowledge, ours is the first study to combine the company size and different types of jobs in one analysis. The finding that mortality risk does not differ by size of company for male white-collar workers is novel. White-collar workers have more job control than blue-collar workers, so a high level of job control may correlate with low mortality risk[28] and may be one factor protecting white-collar workers from the effects of differences in size of company. However, this possibility was not directly explored in the present study, and further examination is needed.

In a study on a group of companies that carried out roughly the same activities for occupational safety and employed roughly the same labor regulations, no consistent associations were found in the relationship between size of company and health check-ups items (eg, blood pressure and alanine aminotransferase).[29] While that study points to the importance of industrial health and safety activities, one challenge that has been recognized in Japan is the lack of industrial health and safety activities at small- and medium-sized companies.[5] The extent of differences in the impact on future health for small- and medium-sized companies compared to large companies had not previously been sufficiently clarified. The results of our study suggest that differences in company size affect mortality in old age. In other words, company size is one factor causing health inequalities. In Japan, small- and medium-sized companies make up 99.7% of all companies and 68.8% of all employees work at small- and medium-sized companies.[30] Company size may therefore have a huge impact on mortality. Reducing

TABLE 3 Mortality hazard ratios for the size of company of the longest-held job among men

				Model 1		Model 2		Model 3		Model 4	
	N	Deaths	Person-years	HR	95%CI	HR	95%CI	HR	95%CI	HR	95%CI
Total	19 260	2870	105 324								
1-9	3274	544	17 807	ref		ref		ref		ref	
10-49	4213	677	23 017	0.96	0.86-1.08	0.96	0.86-1.08	0.96	0.86-1.07	0.96	0.86-1.08
50-499	5285	787	28 950	0.92	0.83-1.03	0.94	0.84-1.05	0.92	0.82-1.02	0.93	0.83-1.04
500-9999	4053	558	22 210	0.93	0.82-1.05	0.97	0.86-1.09	0.92	0.82-1.04	0.95	0.84-1.08
10 000+	2435	304	13 341	0.78	0.68-0.90	0.84	0.72-0.97	0.77	0.67-0.89	0.81	0.70-0.93
P for trend				.002		.051		.001		.01	
White-collar[a]	7321	983	40 139								
1-9	1020	145	5613	ref		ref		ref		ref	
10-49	1484	215	8147	0.99	0.80-1.22	1.02	0.82-1.26	0.98	0.79-1.21	1.00	0.81-1.24
50-499	1897	260	10 390	0.92	0.75-1.13	0.95	0.77-1.17	0.91	0.74-1.12	0.93	0.76-1.15
500-9999	1751	211	9638	0.92	0.74-1.14	0.97	0.78-1.21	0.93	0.75-1.15	0.94	0.76-1.18
10 000+	1169	152	6352	0.94	0.75-1.19	1.01	0.80-1.28	0.94	0.74-1.18	0.98	0.77-1.24
P for trend				.47		.88		.48		.66	
Pink-collar[b]	4903	703	26 762								
1-9	910	154	4900	ref		ref		ref		ref	
10-49	924	138	5029	0.91	0.72-1.14	0.88	0.70-1.11	0.90	0.72-1.14	0.90	0.72-1.14
50-499	1459	195	8047	0.86	0.70-1.07	0.86	0.69-1.07	0.86	0.69-1.06	0.87	0.70-1.09
500-9999	983	141	5352	0.98	0.77-1.24	0.97	0.77-1.23	0.96	0.76-1.22	1.02	0.80-1.29
10 000+	627	75	3434	0.66	0.50-0.87	0.67	0.51-0.89	0.63	0.47-0.83	0.69	0.52-0.92
P for trend				.03		.051		.01		.09	
Blue-collar[c]	3969	634	21 944								
1-9	636	104	3519	ref		ref		ref		ref	
10-49	926	174	5039	1.12	0.88-1.43	1.12	0.88-1.44	1.10	0.86-1.40	1.12	0.88-1.43
50-499	1116	188	6172	1.00	0.78-1.27	1.03	0.81-1.31	0.98	0.77-1.25	1.00	0.79-1.27
500-9999	880	131	4860	1.02	0.78-1.33	1.09	0.84-1.41	0.98	0.75-1.27	1.02	0.79-1.33
10 000+	411	37	2354	0.59	0.41-0.86	0.65	0.44-0.95	0.58	0.40-0.85	0.60	0.41-0.87
P for trend				.03		.14		.02		.03	
Other	1899	328	10 260								
1-9	487	105	2573	ref		ref		ref		ref	
10-49	580	89	3200	0.74	0.55-0.99	0.70	0.52-0.93	0.75	0.56-1.001	0.75	0.56-1.01
50-499	487	79	2610	0.82	0.61-1.11	0.84	0.62-1.13	0.81	0.60-1.15	0.86	0.64-1.15
500-9999	216	37	1176	0.75	0.52-1.10	0.75	0.51-1.11	0.79	0.54-1.15	0.81	0.55-1.19
10 000+	129	18	701	0.60	0.36-1.00	0.61	0.36-1.02	0.56	0.33-0.94	0.65	0.39-1.10
P for trend				.047		.07		.04		.13	

Note: Model 1 adjusts for age, educational attainment, type of longest-held job (only in analysis of all participants), and municipalities.

Model 2 adjusts for age, educational attainment, type of longest-held job (only in analysis of all participants), municipalities, and behavioral factors (walking time, frequency of fruit and vegetable consumption, alcohol consumption status, smoking status, and health checkups).

Model 3 adjusts for age, educational attainment, type of longest-held job (only in analysis of all participants), municipalities, and self-reported medical condition for three major diseases (cancer, heart disease, and stroke) in old age.

Model 4 adjusts for age, educational attainment, type of longest-held job (only in analysis of all participants), municipalities, and annual equivalized income in old age.

Abbreviation: HR, Hazards ratio.

Missing values for the type of longest-held job have been omitted.

[a]White-collar: professional/technical and administrative.

[b]Pink-collar: clerical and sales/service.

[c]Blue-collar: skilled/labor.

TABLE 4 Mortality hazard ratios for the size of company of the longest-held job among women

				Model 1		Model 2		Model 3		Model 4	
	N	Deaths	Person-years	HR	95%CI	HR	95%CI	HR	95%CI	HR	95%CI
Total	16 158	1065	92 190								
1-9	4177	311	23 871	ref		ref		ref		ref	
10-49	5252	350	30 108	0.89	0.76-1.03	0.89	0.76-1.03	0.89	0.76-1.04	0.89	0.76-1.04
50-499	4492	284	25 531	0.95	0.80-1.12	0.95	0.81-1.12	0.95	0.81-1.12	0.96	0.81-1.13
500-9999	1605	83	9149	0.87	0.68-1.11	0.88	0.69-1.13	0.87	0.68-1.11	0.88	0.69-1.13
10 000+	632	37	3531	0.94	0.66-1.32	0.97	0.68-1.36	0.89	0.63-1.26	0.97	0.69-1.37
P for trend				.41		.53		.35		.55	
White-collar[a]	2143	125	12 246								
1-9	516	34	2930	ref		ref		ref		ref	
10-49	732	39	4212	0.84	0.52-1.35	0.77	0.47-1.24	0.82	0.51-1.31	0.85	0.53-1.37
50-499	627	38	3556	1.04	0.65-1.69	1.03	0.64-1.67	1.01	0.63-1.64	1.05	0.65-1.71
500-9999	188	7	1095	0.69	0.30-1.57	0.70	0.31-1.61	0.63	0.28-1.45	0.70	0.31-1.61
10 000+	80	7	453	1.34	0.58-3.09	1.14	0.49-2.66	1.37	0.59-3.16	1.38	0.60-3.18
P for trend				.82		.89		.91		.77	
Pink-collar[b]	7698	439	43 731								
1-9	2109	147	12 076	ref		ref		ref		ref	
10-49	2233	127	12 744	0.89	0.70-1.13	0.88	0.70-1.12	0.94	0.74-1.19	0.90	0.71-1.15
50-499	2028	109	11 432	0.95	0.74-1.23	0.96	0.75-1.24	0.97	0.76-1.25	0.97	0.75-1.25
500-9999	910	38	5143	0.79	0.55-1.13	0.81	0.56-1.16	0.82	0.57-1.18	0.81	0.56-1.17
10 000+	418	18	2336	0.73	0.45-1.21	0.73	0.44-1.20	0.72	0.44-1.18	0.78	0.47-1.28
P for trend				.17		.21		.18		.26	
Blue-collar[c]	1887	168	10 924								
1-9	329	33	1897	ref		ref		ref		ref	
10-49	615	58	3566	0.93	0.61-1.44	0.96	0.62-1.49	0.89	0.57-1.38	0.92	0.60-1.42
50-499	686	61	3952	1.10	0.71-1.70	1.11	0.71-1.72	1.06	0.69-1.65	1.09	0.71-1.69
500-9999	216	14	1275	0.94	0.50-1.78	0.90	0.47-1.70	0.92	0.49-1.75	0.93	0.49-1.76
10 000+	41	2	235	0.87	0.21-3.68	1.00	0.24-4.22	0.93	0.22-3.91	0.88	0.21-3.70
P for trend				.84		.89		.84		.85	
Other	2937	228	16 805								
1-9	834	68	4783	ref		ref		ref		ref	
10-49	1111	87	6380	0.89	0.64-1.22	0.86	0.62-1.18	0.89	0.65-1.23	0.90	0.65-1.24
50-499	762	56	4346	0.94	0.65-1.35	0.91	0.63-1.31	0.95	0.66-1.37	0.96	0.67-1.37
500-9999	180	11	1026	0.88	0.47-1.68	0.86	0.45-1.65	0.97	0.51-1.86	0.88	0.46-1.68
10 000+	50	6	270	1.59	0.69-3.70	1.71	0.73-3.99	1.44	0.61-3.38	1.63	0.70-3.80
P for trend				.89		.94		.82		.84	

Note: Model 1 adjusts for age, educational attainment, type of longest-held job (only in analysis of all participants), and municipalities.

Model 2 adjusts for age, educational attainment, type of longest-held job (only in analysis of all participants), municipalities, and behavioral factors (walking time, frequency of fruit and vegetable consumption, alcohol consumption status, smoking status, and health checkups).

Model 3 adjusts for age, educational attainment, type of longest-held job (only in analysis of all participants), municipalities, and self-reported medical condition for three major diseases (cancer, heart disease, and stroke) in old age.

Model 4 adjusts for age, educational attainment, type of longest-held job (only in analysis of all participants), municipalities, and annual equivalized income in old age.

Missing values for the type of longest-held job have been omitted.

Abbreviation: HR, Hazards ratio.

[a]White-collar: professional/technical and administrative.

[b]Pink-collar: clerical and sales/service.

[c]Blue-collar: skilled/labor.

inequalities requires more than just focusing solely on the most disadvantaged individuals. Activities scaled to the level of disadvantage should be rolled out universally as a type of proportionate universalism.[31] The findings from the present study are therefore important evidence showing the necessity of dedicated measures for small- and medium-sized companies and proportionate universalism tailored to company size. To consider such measures, research is needed to determine the mechanisms and mediating factors resulting in health inequalities in old age due to differences in size of company.

This study has some strengths. To the best of our knowledge, it is the first to examine the association between size of company of the longest-held job and mortality risk in older adults. Furthermore, we used a large population-based longitudinal dataset ranging from Hokkaido in northernmost Japan to the Kyushu region in southernmost Japan. However, it has several limitations. First is that the response rate was 65.1%, raising the possibility that this data does not provide a full picture of our study population. In addition, about one in four valid respondents were removed from analysis because their response to the question on size of company of the longest-held job was "unknown" or missing (part of the exclusion criteria). Compared to respondents who were included in the analysis (men: 54.4%, women: 45.6%), those excluded respondents had a higher percentage of women (men: 28.5%, women: 71.5%). Caution must therefore be used especially when generalizing these results to women. In addition, the proportion of companies with 1-9 employees (21.0%) and companies with 10-49 employees (26.7%) were higher than proportions found in the 2014 economic census for business activity (9.3% and 19.4%, respectively).[30] Type of work, work environment, and other factors over the long term may have affected the results of this study, making them less applicable to groups with other social backgrounds (eg, current workers who are under age 65). As the second limitation, the association between size of company and mortality rate may have been underestimated as we focused only on functionally independent individuals aged 65 or older and did not include those who became certified for need of long-term care or died before we conducted our research. The third limitation was that we were unable to clearly separate participants who worked for companies and those who did not because they were self-employed or were public servants, for example. Although we excluded agriculture/forestry/fishery workers as they are often self-employed, our analysis may still have included others who did not work at a company. The fourth limitation was that self-reported questionnaires were used in this research. Responses about past employment at companies may be affected by recall bias. Respondents who had not worked for many years or who had changed jobs numerous times may be especially vulnerable to recall bias. The fifth limitation was that we were limited to the types of indicators we could use. As size of company ranged quite broadly in our study, our categories differed from those often used in existing statistical data and previous studies. In addition, we were unable to examine the effects of lifestyle habits and health status prior to starting work at the longest-held job, length of employment at the longest-held job, or employment outside of the company of the longest-held job. For health behaviors, we were only able to use frequency as an indicator. Future studies should take these points into account as well.

In conclusion, among Japanese men, mortality rate in old age may decrease with increasing size of company of the longest-held job. To reduce health inequalities due to differences in size of company, the mechanisms and mediating factors need to be determined and reflected in labor policies.

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DISCLOSURES

Approval of the research protocol: The Research Ethics Committee of the Nihon Fukushi University Ethics Committee (application number: 10-05) reviewed and approved the aims and procedures of this study. *Informed consent*: Informed consent was obtained from all individual participants included in the study. *Registry and the registration no. of the study/trial*: N/A. *Animal studies*: N/A. *Conflict of interest*: Authors declare no conflict of interests for this article.

AUTHOR CONTRIBUTIONS

SK conducted the analysis and wrote the manuscript in collaboration with T Tsuji, T Takamiya, HK, and SI, and DT wrote the first draft of the manuscript. YK, MY, YK, and KK provided the feedback and suggestions. All authors read the manuscript and approved to submission.

ETHICAL APPROVAL

Ethical approval for the study was obtained from the Nihon Fukushi University Ethics Committee (application number: 10-05). This study was performed in accordance with the principles of the Declaration of Helsinki. Informed consent was obtained from all participants.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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Article

Association between Neighborhood Environment and Quality of Sleep in Older Adult Residents Living in Japan: The JAGES 2010 Cross-Sectional Study

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Abstract: Poor sleep is associated with lifestyle, however, few studies have addressed the association between sleep quality and the neighborhood environment. This study aimed to investigate the associations between living environment factors and sleep quality in older people. Participants were community-dwelling people aged ≥65 years who participated in the 2010 Japanese Gerontological Evaluation Study. The data of 16,650 people (8102 men, 8548 women) were analyzed. Sleep quality (good or poor) was evaluated using a self-administered questionnaire. Multilevel Poisson regression analysis stratified by depressive status (measured by the Geriatric Depression Scale-15 [GDS]) was conducted with sleep quality as the dependent variable and social and physical environmental factors as explanatory variables. The 12,469 non-depressive respondents and 4181 depressive respondents were evaluated. The regression analysis indicated that non-depressive participants slept better if they lived in environments with few hills or steps (prevalence ratio [PR] = 0.75, 95% CI: 0.56–0.9) and with places where they felt free to drop in (PR = 0.51, 95% CI: 0.26–0.98). For depressive participants, these associations were not evident. Living alone, poor self-rated health, low income, and unemployment were associated with poor sleep quality. In addition to support with these individual factors, improving environmental factors at the neighborhood level may improve the sleep quality of community-dwelling older adults.

Keywords: multilevel Poisson regression; older adults; physical environment; sleep quality; social environment

1. Introduction

Sleep is one of the most important lifestyle factors for maintaining a good health status, alongside diet and exercise. Poor sleep causes lifestyle-related diseases such as hypertension, diabetes mellitus, or metabolic syndrome [1–3] and even psychiatric diseases such as depression [4–6]. In addition, it has been recently elucidated that poor sleep is associated with cognitive impairment and the onset of dementia in older adults [7–9].

One in five Japanese persons experiences sleep problems, and this proportion is increased to one in three persons in the older population. Poor sleep is a serious problem in older adults. The duration of sleep is generally longer in old age than in young age, but the quality of sleep is reduced due to light sleep, interrupted sleep, and/or early awakening, which then cause sleepiness during the day and declining activity [10]. Additional causes of poor sleep such as insomnia are particularly prevalent in older adults. For instance, negative life events such as retirement, bereavement, and living alone may be psychiatric stressors [11], which cause sleep disorders. Consequently, such persons lose social roles and their physical and mental activity is reduced [12]. Finally, they tend to be affected by physical and mental diseases [13]. Such negative cycles can occur in older adults.

Social determinants of health have become topics of study in recent years, and it has become clear that some factors that are not amenable to improvement by individual efforts alone also have an effect on health. The World Health Organization (WHO) Adelaide Statement on Health in All Policies issued in 2010 emphasized that government objectives are best achieved when all sectors include health and well-being as key components of policy development [14]. In light of this reality, there is an increasing need to create local environments that encourage people to remain healthy as they age. In 2011, the WHO set up the WHO Global Network of Age-friendly Cities and Communities with a focus on social determinants of health. Baglioni et al. [4] and Pugh et al. [15] have suggested that the neighborhood environment may affect the functional health of older people. There is thus an increasing awareness that health support must involve not only support at the individual level, but also community-level support.

Most previous studies of sleep have addressed its association with individual factors such as sex, age, income, and educational achievement [16,17]. In terms of the association between sleep and community-level environmental factors that affect individuals, a few studies have investigated the associations of public order and social capital with sleep at the individual level [18–20]. However, no study has yet addressed the association between sleep quality and the neighborhood physical environment using multilevel analysis.

Because older people spend the vast majority of their time in residential neighborhoods, they are highly susceptible to the impact of the local environment in the neighborhood. In addition to public order and social capital, the physical environment may also affect sleep in older people. Therefore, in this study, we aimed to perform a multilevel analysis of the association between environmental factors in Japanese residential neighborhoods and sleep quality.

2. Materials and Methods

2.1. Participants

The subjects of this study were participants of the Japanese Gerontological Evaluation Study (JAGES) in 2010 [21]. Participants were community-dwelling people aged ≥65 years who lived in 31 municipalities in 11 of the 47 prefectures in Japan. Social and physical environments surrounding the participants varied by municipalities: for instance, socially between tight bonding communities and those with less bonding; and physically between highly populated urban cities and less populated rural areas. Such environmental variety affects lifestyle and even physical and mental health outcomes which can cause health disparities [22]. The participants were not certified to need long-term care. A self-administered questionnaire was distributed by postal mail to each of the 160,382 eligible participants between August 2010 and January 2012. The participants primarily responded to the

questions by themselves. The questionnaire included five modules, and each module was sent randomly to one-fifth of the participants. Items to evaluate sleep quality were included in one of the five modules.

2.2. Definition of Sleep Quality

Sleep quality (good or poor) was evaluated on the basis of the participant's response to the self-administered questionnaire. The quality domain from the Pittsburgh Sleep Quality Index (PSQI) was applied to evaluate sleep quality. The PSQI sleep quality item asks "During the past month, how would you rate your sleep quality overall?" with possible responses: "very good", "fairly good", "fairly bad", and "very bad". This single item was selected as the total PSQI score and incorporates information of other domains of sleep in the PSQI [23] (e.g., sleep timing and continuity). In addition, the four responses were dichotomized into two values, good (very good or fairly good) or poor (fairly bad or very bad) and were used as the dependent variable.

2.3. Explanatory Variables

2.3.1. Individual-Level Variables

We evaluated the association between sleep quality and the following individual-level factors: sex; age (65–69, 70–74, 75–79, 80–84, ≥85 years); living alone (yes, no); self-rated health (good, poor); employment (yes, no); equalized household income (<2 million yen, 2–3.99 million yen, ≥4 million yen); education (<6 years, 6–9 years, 10–12 years, ≥13 years); daily walking time (<60 min, ≥60 min); and any medical treatments received for conditions other than sleep disorders such as hypertension, diabetes, respiratory diseases, cancer, heart disease, or any diseases. Depressive status (non-depressive or depressive) defined by the Geriatric depression scale (GDS)-15 (GDS score of <5: non-depressive or ≥5: depressive) was also included as an individual variable in the main analysis. The respondents were stratified into two groups: individuals with a depressive trend as defined by a GDS score of ≥5, and those without a depressive trend as defined by a GDS score of < 5 [24,25].

2.3.2. Neighborhood-Level Variables

According to a previous study, neighborhood environment was evaluated by two components, the social environment and physical environment [26]. For evaluation of the social environment, we applied a modified version of health-related social capital indices [27], which are composed of the following three dimensions: (1) civic participation, (2) social cohesion, and (3) reciprocity. Civic participation was scored by asking participants whether or not they took part in a volunteer group, sports group, or hobby activity at least once per month or less than once per month, and calculating the rate of participation in each group in the school district. Civic participation was therefore scored as follows: (rate of volunteer group participation × 0.6) + (rate of sports group participation × 0.8) + (rate of hobby activity × 0.9). Social cohesion was scored by asking respondents about community trust, norms of reciprocity, and community attachment on a five-point scale ("strongly agree", "somewhat agree", "neither agree nor disagree", "somewhat disagree", and "completely disagree"), with the responses "strongly agree" and "somewhat agree" categorized as "agree" and "neither agree nor disagree," "somewhat disagree," and "completely disagree" categorized as "disagree," and calculating the rate of "agree." Social cohesion was therefore scored as follows: (rate of "agree" to community trust × 0.9) + (rate of "agree" to norms of reciprocity × 0.8) + (rate of "agree" to community attachment × 0.7). Reciprocity was evaluated by asking whether or not participants received emotional support, to whom they were providing emotional support, and from whom they were receiving instrumental support, with the responses categorized as yes or no, and calculated the rate of "yes." Reciprocity was therefore scored as follows: (rate of "yes" to receiving emotional support × 0.8) + (rate of "yes" to providing emotional support × 0.8) + (rate of "yes" to receiving instrumental support × 0.7).

Regarding the surrounding physical environment, eight items were evaluated. We asked whether the respondents had each of following environmental items within 1 km of their residence: (1) "Locations with noticeable graffiti or undisposed garbage"; (2) "Parks or foot paths suitable for exercise or walking"; (3) "Locations difficult for walking, such as hills or steps"; (4) "Roads or crossroads with a great risk of traffic accidents"; (5) "Fascinating views or buildings"; (6) "Shops or facilities selling fresh fruits and vegetables"; (7) "Dangerous places when walking alone at night"; and (8) "Houses or facilities where you feel free to drop in." The potential responses were "Many", "Some", "Few", "None", and "I don't know." The five responses were dichotomized into two values: Yes ("Many" or "Some") or No ("Few" or "None" or "I don't know"), and used as explanatory variables.

2.4. Statistical Analysis

Many previous studies have reported a significant association between sleep and depression [18,20,26]. Thus, we stratified the responses by depressive status to evaluate sleep quality after testing the potential interactions between depressive status and each of the explanatory variables on sleep quality.

First, the baseline characteristics of the respondents were stratified by depressive status (GDS score of <5 or ≥5). Univariate analyses using the chi-square test were used to evaluate the associations between sleep quality and each of the individual characteristics. Data missing the outcome variable or GDS score were excluded from the analysis. If data were missing other explanatory variables, the corresponding observation was assigned to the category of the missing variable [28]. The threshold for statistical significance was set at P-value (p) < 0.05 in a two-tail test.

Second, neighborhood characteristics in the school districts were evaluated. The school district was used as the neighborhood unit, which is a proxy for a geographical area that is easy for older adults to navigate [29]. Social capital indices in each school district were calculated. Applicable rates for the eight items of the surrounding physical environment were also calculated at each school district unit. Third, a multivariate analysis was conducted to explore the factors associated with sleep quality status including neighborhood-level factors using a multilevel Poisson regression model. To avoid overestimation of odds ratios with logistic regression analysis [30], since the proportion of people with poor sleep was >10%, we used a Poisson regression model with strong dispersion. We conceptualized the analysis in a multilevel structure, comprising individual factors (individual-level) and nested within school district factors (neighborhood-level). We fitted the data using multilevel Poisson regression procedures with a random intercept model, adjusting for both individual and neighborhood levels as fixed effects and setting sleep quality as the dependent variable. The method of estimation was a restricted maximum likelihood procedure. The first set of analyses involved estimating the null model (Model 1). The null model allows for the decomposition of variance in sleep quality to determine whether it was attributable to neighborhood-level and between-person variation. Next, the modeling was performed in three steps: Model 2, only individual-level factors were added; Model 3 had both individual-level factors and neighborhood-level social environmental factors; and Model 4 had both individual-level factors and neighborhood-level surrounding physical environmental factors. The fixed effect results are presented as prevalence ratios (PRs) with 95% confidence intervals (CIs). The random effect results are presented as neighborhood-level random variance with standard error (SE). The calculated proportional changes in variance (PCV). Statistical analyses were performed using STATA version 14 (StataCorp, College Station, TX, USA).

2.5. Ethical Considerations

The study protocol for the JAGES project was approved by the Ethics Committee of Nihon Fukushi University (No. 10-05). A letter informing all potential participants of the ethical considerations, including the study methods, was enclosed with the survey, and the return of the completed survey questionnaire was considered to indicate the provision of informed consent.

3. Results

3.1. Characteristics of the Respondents

A total of 106,460 people responded to the survey (response rate, 66.4%; Figure 1). Among the respondents, 23,320 were sent the module (module "D") that included items related to sleep quality to be analyzed. Among the eligible respondents, people with sleep disorder (n = 1574) and those who did not respond to the sleep quality and GDS score module (n = 5096) were excluded. A question which asks about current diseases in the questionnaire could identify sleep disorders (e.g., insomnia or snoring). Finally, the data of 16,650 people (8102 men, 8548 women) were analyzed.

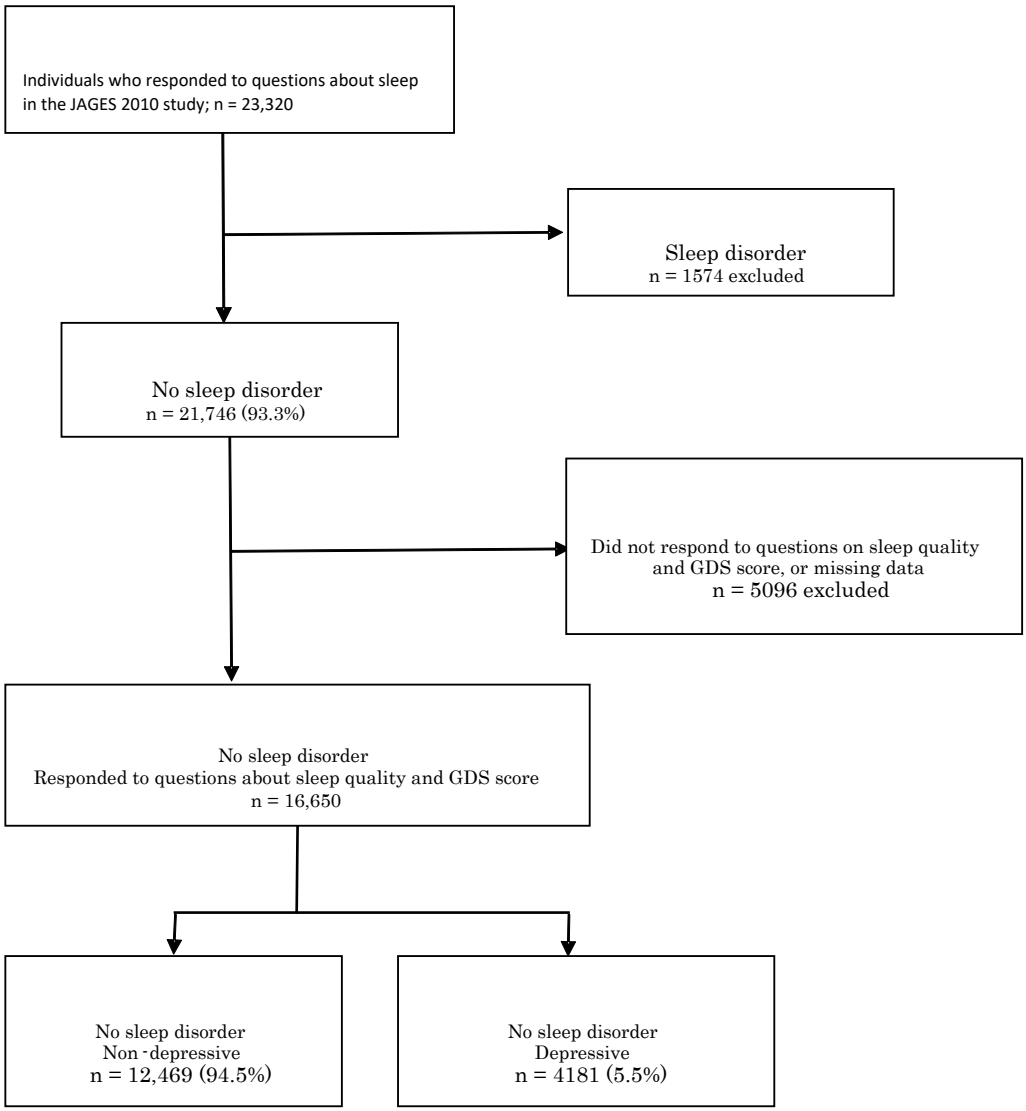

Figure 1. Flow chart of the enrollment process of the study participants. People with sleep disorders (n = 1574) and those who did not respond to the sleep quality module (n = 5096) were excluded. Finally, the data of 16,650 people (12,469 without depressive status, 4181 with depressive status) were analyzed.

The average age of all respondents was 73.9 ± 6.2 years (range 65–101 years). The baseline characteristics of the respondents are provided in Table 1. Among the 12,469 non-depressive respondents (GDS score of <5), 2286 (18.3%) had poor sleep. Of the 4181 depressive respondents (GDS score of ≥5), 1785 (43.3%) had poor sleep. The rates of poor sleep significantly differed between non-depressive and depressive respondents ($p < 0.001$; Figure 2).

Table 1. Characteristics of the study participants divided by sleep quality (good or poor).

Characteristic	Variable	Good (n = 12,579)		Poor (n = 4071)		
		n	%	n	%	*p* *
Sex	male	6227	49.5	1875	46.06	<0.001
	female	6352	50.5	2196	53.94	
Age (years)	65–69	3948	31.39	1356	33.31	0.002
	70–74	3662	29.11	1249	30.68	
	75–79	2663	21.17	807	19.82	
	80–84	1556	12.37	446	10.96	
	≥85	750	5.96	213	5.23	
Living alone	no	11,089	88.15	3460	84.99	<0.001 †
	yes	1355	10.77	562	13.8	
	missing	135	1.07	49	1.2	
Self-rated health	fair	10,729	85.29	2732	67.11	<0.001 †
	poor	1668	13.26	1276	31.34	
	missing	182	1.45	63	1.55	
Job	having	2996	23.82	757	18.59	<0.001 †
	no	8581	68.22	2969	72.93	
	missing	1002	7.97	345	8.47	
Equivalent income (million yen)	<200	6783	53.92	2525	62.02	<0.001 †
	200–400	4402	34.99	1244	30.56	
	≥400	1394	11.08	302	7.42	
Education (year)	<6	247	1.96	105	2.58	<0.001
	6–9	5375	42.73	1868	45.89	
	10–12	4517	35.91	1377	33.82	
	≥13	2256	17.93	641	15.75	
	other	59	0.47	32	0.79	
	missing	125	0.99	48	1.18	
Walking time (min)	<60	7780	61.85	2778	68.24	<0.001 †
	≥60	4162	33.09	1082	26.58	
	missing	637	5.06	211	5.18	
Treatment	yes	8378	66.6	2917	71.65	<0.001 †
	no	3316	26.36	843	20.71	
	missing	885	7.04	311	7.64	
Depressive status	GDS score of <5	10,183	80.95	2286	56.15	<0.001
	GDS score of ≥5	2396	19.05	1785	43.85	
Volunteer group	≥ 1/month	8818	70.1	2931	72	0.027 †
	< 1/month	1198	9.52	338	8.3	
	missing	2563	20.38	802	19.7	
Sports group	≥ 1/month	7930	63.04	2720	66.81	<0.001 †
	< 1/month	2540	20.19	660	16.21	
	missing	2109	16.77	691	16.97	
Hobby activity	≥ 1/month	6675	53.06	2305	56.62	<0.001 †
	< 1/month	4074	32.39	1173	28.81	
	missing	1830	14.55	593	14.57	
Community trust	very	9136	72.63	2528	62.1	<0.001 †
	slightly	2931	23.3	1400	34.39	
	missing	512	4.07	143	3.51	
Norms of reciprocity	very	7374	58.62	1959	48.12	<0.001 †
	slightly	4652	36.98	1967	48.32	
	missing	553	4.4	145	3.56	
Community attachment	very	10,590	84.19	3023	74.26	<0.001 †
	slightly	1783	14.17	1003	24.64	
	missing	206	1.64	45	1.11	
Receive emotional support	no	11,338	90.13	3574	87.79	<0.001 †
	any one	611	4.86	325	7.98	
	missing	630	5.01	172	4.23	
Provide emotional support	no	11,115	88.36	3503	86.05	<0.001 †
	any one	781	6.21	365	8.97	
	missing	683	5.43	203	4.99	
Receive instrumental support	no	11,607	92.27	3633	89.24	<0.001 †
	any one	415	3.3	289	7.1	
	missing	557	4.43	149	3.66	

Table 1. *Cont.*

Characteristic	Variable	Good (n = 12,579)		Poor (n = 4071)		
		n	%	n	%	*p* *
Locations with graffiti or garbage	present	3349	26.62	1246	30.61	<0.001 †
	absent	9009	71.62	2764	67.89	
	missing	221	1.76	61	1.5	
Parks/foot paths suitable for exercise/walking	present	9009	71.62	2629	64.58	<0.001 †
	absent	3419	27.18	1408	34.59	
	missing	151	1.2	34	0.84	
Locations difficult for walking (hills or steps)	present	4939	39.26	1722	42.3	0.002 †
	absent	7523	59.81	2316	56.89	
	missing	117	0.93	33	0.81	
Roads/crossroads with risk of traffic accidents	present	8152	64.81	2792	68.58	<0.001 †
	absent	4291	34.11	1239	30.43	
	missing	136	1.08	40	0.98	
Fascinating views or buildings	present	5088	40.45	1378	33.85	<0.001 †
	absent	7298	58.02	2636	64.75	
	missing	193	1.53	57	1.4	
Shops or facilities selling fresh fruits & vegetables	present	9427	74.94	2816	69.17	<0.001 †
	absent	3006	23.9	1229	30.19	
	missing	146	1.16	26	0.64	
Dangerous places for walking alone at night	present	7444	59.18	2552	62.69	<0.001 †
	absent	4973	39.53	1473	36.18	
	missing	162	1.29	46	1.13	
Houses or facilities where you feel free to drop in	present	5279	41.97	1337	32.84	<0.001 †
	absent	7137	56.74	2682	65.88	
	missing	163	1.3	52	1.28	

* Chi-square test. † Scheffe's multiple comparison procedure; Significant difference was found between GDS score of <5 living alone: no and yes ($p < 0.001$), Self-rated health: fair and poor ($p < 0.001$), poor and missing ($p < 0.001$),Job: having and no ($p < 0.001$), having and missing($p < 0.001$), Equivalent income: <200 million yen and 200–400 million yen ($p < 0.001$), <200 million yen and ≥400 million yen ($p < 0.001$), 200–400 million yen and ≥400 million yen ($p = 0.002$), Walking time: <60min and ≥60 min ($p < 0.001$), ≥60min and missing ($p = 0.028$), Treatment: yes and no ($p < 0.001$), no and missing ($p < 0.001$),depressive status: GDS score of <5 and GDS score of ≥5: $p < 0.001$),Volunteer group: ≥ 1/month and <1/month ($p = 0.042$),Sports group:≥ 1/month and < 1/month ($p < 0.001$), 1/month and <missing ($p = 0.001$), Hobby activity: ≥1/month and <1/month ($p < 0.001$), Community trus: t very and slightly ($p < 0.001$), slightly and missing ($p < 0.001$), Norms of reciprocity: very and slightly ($p < 0.001$), slightly and missing ($p < 0.001$)), Community attachment: very and slightly ($p < 0.001$), slightly and missing ($p < 0.001$), Receive emotional support: no and any one ($p < 0.001$), no and missing ($p < 0.001$), Provide emotional support: no and any one ($p < 0.001$), no and missing ($p < 0.001$),Receive instrumental support: no and any one ($p < 0.001$), no and missing ($p < 0.001$), Locations with graffiti or garbage: present and absent ($p < 0.001$), and absent and missing ($p < 0.001$), Parks/foot paths suitable for exercise/walking: present and absent ($p < 0.001$), absent and missing ($p = 0.004$), Roads/crossroads with risk of traffic accidents: present and absent ($p < 0.001$), Fascinating views or buildings: present and absent ($p < 0.001$), Shops or facilities selling fresh fruits & vegetables: present and absent ($p < 0.001$), absent and no ($p < 0.001$), Dangerous places for Walking: alone at night: present and absent ($p < 0.001$), Houses or facilities where you feel free to drop in: present and absent ($p < 0.001$).

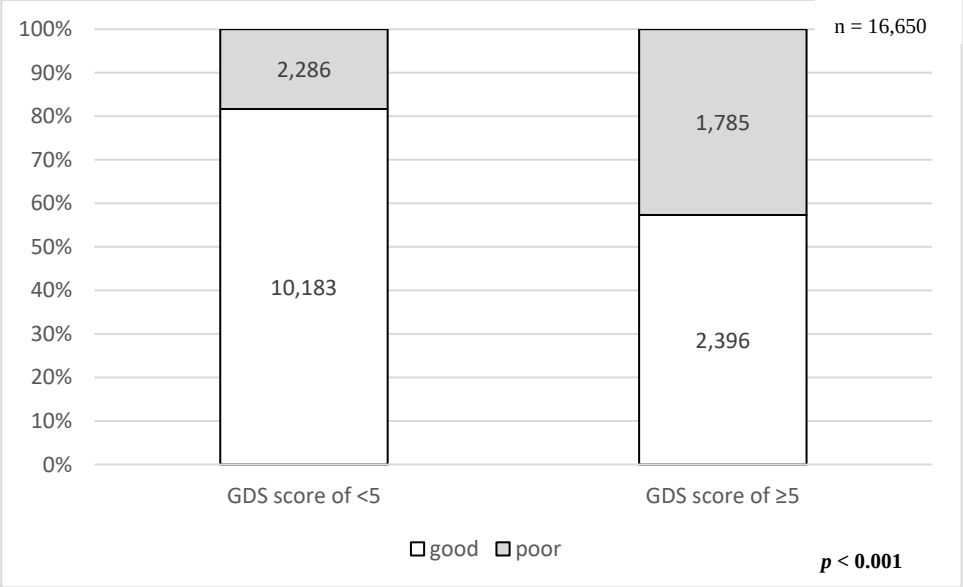

Figure 2. Prevalence of poor sleep between depressive and non-depressive participants. The rate of poor sleep in depressive participants (Geriatric Depression Scale [GDS] score of ≥5) was significantly higher than that in non-depressive participants (GDS score of <5) ($p < 0.001$).

In the non-depressive respondents, the proportion of women with poor sleep was significantly higher (55.8%) than the proportion of women with good sleep (50.6%; $p < 0.001$). Poor sleepers tended to be younger than good sleepers ($p < 0.001$). The rates of living alone, poor self-rated health, and not working were respectively higher in poor sleepers than in good sleepers (all $p < 0.001$). Regarding socioeconomic status, lower equivalent income and shorter educational attainment were observed more frequently in poor sleepers (both $p < 0.001$). Walking time was significantly shorter in poor sleepers than in good sleepers ($p < 0.001$). In addition, the rate of people who has any co-morbidity was higher in poor sleepers than in good sleepers ($p < 0.001$).

At the individual level, there was no association between poor sleep quality and civic participation in volunteer, sports, or hobby groups. In contrast, low scores for community trust, norms of reciprocity, and community attachment were significantly associated with poor sleep quality ($p < 0.001$). This result was the same for both depressive and non-depressive respondents. Non-depressive respondents who were not receiving instrumental support had significantly poorer sleep quality ($p < 0.007$). In depressive respondents, those who were not receiving emotional support nor receiving instrumental support had significantly poorer sleep quality (Table 2).

Table 2. Characteristics of participants divided by depressive status (GDS score of ≥5 or <5) and sleep quality (good or poor).

		GDS Score of <5 (n = 12,469)					GDS Score of ≥5 (n = 4181)				
		Good (n = 10,183)		Poor (n = 2286)			Good (n = 2396)		Poor (n = 1785)		
		n	%	n	%	*p* *	n	%	n	%	*p* *
Sex	male	5029	49.4	1011	44.2	<0.001	1198	50.0	864	48.4	0.307
	female	5154	50.6	1275	55.8		1198	50.0	921	51.6	
Age (years)	65–69	3304	32.5	830	36.3	<0.001 †	644	26.9	526	29.5	0.008
	70–74	3010	29.6	723	31.6		652	27.2	526	29.5	
	75–79	2135	21.0	421	18.4		528	22.0	386	21.6	
	80–84	1206	11.8	239	10.5		350	14.6	207	11.6	
	≥85	528	5.2	73	3.2		222	9.3	140	7.8	
Living alone	no	9052	88.9	1996	87.3	0.030 †	2037	85.0	1464	82.0	0.021
	yes	1021	10.0	270	11.8		334	13.9	292	16.4	
	missing	110	1.1	20	0.9		25	1.0	29	1.6	
Self-rated health	fair	9126	89.6	1812	79.3	<0.001 †	1603	66.9	920	51.5	<0.001 †
	poor	920	9.0	443	19.4		748	31.2	833	46.7	
	missing	137	1.4	31	1.4		45	1.9	32	1.8	
Job	having	2591	25.4	487	21.3	<0.001 †	405	16.9	270	15.1	<0.001
	no	6805	66.8	1631	71.4		1776	74.1	1338	75.0	
	missing	787	7.7	168	7.4		215	9.0	177	9.9	
Equivalent income (million yen)	<200	5170	50.8	1270	55.6	<0.001 †	1613	67.3	1255	70.3	0.087
	200–400	3761	36.9	801	35.0		641	26.8	443	24.8	
	≥400	1252	12.3	215	9.4		142	5.9	87	4.9	
Education (year)	<6	162	1.6	43	1.9	0.476	85	3.6	62	3.5	0.420
	6–9	4211	41.4	975	42.7		1164	48.6	893	50.0	
	10–12	3737	36.7	834	36.5		780	32.6	543	30.4	
	≥13	84	0.8	17	0.7		41	1.7	31	1.7	
	other	1944	19.1	404	17.7		312	13.0	237	13.3	
	missing	45	0.4	13	0.6		14	0.6	19	1.1	
Walking time (min)	<60	6104	59.9	1466	64.1	<0.001 †	1676	70.0	1312	73.5	0.042
	≥60	3585	35.2	703	30.8		577	24.1	379	21.2	
	missing	494	4.9	117	5.1		143	6.0	94	5.3	
Treatment	yes	6655	65.4	1582	69.2	<0.001 †	1723	71.9	1335	74.8	0.065
	no	2835	27.8	535	23.4		481	20.1	308	17.3	
	missing	693	6.8	169	7.4		192	8.0	142	8.0	
Volunteer group	≥1/month	7083	69.6	1592	69.6	0.692	1735	72.4	1339	75.0	0.161
	<1/month	1077	10.6	253	11.1		121	5.1	85	4.8	
	missing	2023	19.9	441	19.3		540	22.5	361	20.2	
Sports group	≥1/month	6254	61.4	1427	62.4	0.572	1676	70.0	1293	72.4	0.147
	<1/month	2269	22.3	487	21.3		271	11.3	173	9.7	
	missing	1660	16.3	372	16.3		449	18.7	319	17.9	
Hobby activity	≥1/month	5157	50.6	1139	49.8	0.439	1518	63.4	1166	65.3	0.423
	<1/month	3602	35.4	840	36.8		472	19.7	333	18.7	
	missing	1424	14.0	307	13.4		406	16.9	286	16.0	
Community trust	very	7704	75.7	1598	69.9	<0.001 †	1432	59.8	930	52.1	<0.001 †
	slightly	2079	20.4	613	26.8		852	35.6	787	44.1	
	missing	400	3.9	75	3.3		112	4.7	68	3.8	
Norms of reciprocity	very	6302	61.9	1255	54.9	<0.001 †	1072	44.7	704	39.4	<0.001 †
	slightly	3451	33.9	951	41.6		1201	50.1	1016	56.9	
	missing	430	4.2	80	3.5		123	5.1	65	3.6	
Community attachment	very	8836	86.8	1884	82.4	<0.001 †	1754	73.2	1139	63.8	<0.001
	slightly	1174	11.5	382	16.7		609	25.4	621	34.8	
	missing	173	1.7	20	0.9		33	1.4	25	1.4	
Receive emotional support	no	389	3.8	92	4	0.135	222	9.3	233	13.1	<0.001 †
	any one	9285	91.2	2102	92		2053	85.7	1472	82.5	
	missing	509	5	92	4		121	5.1	80	4.5	
Provide emotional support	no	467	4.6	112	4.9	0.288	314	13.1	253	14.2	0.541
	any one	9176	90.1	2070	90.6		1939	80.9	1433	80.3	
	missing	540	5.3	104	4.6		143	6	99	5.6	
Receive instrumental support	no	244	2.4	78	3.41	0.007	171	7.1	211	11.8	<0.001 †
	any one	9500	93.29	2126	93		2107	87.9	1507	84.4	
	missing	439	4.3	82	3.6		118	4.9	67	3.8	
Locations with graffiti or garbage	present	7844	77.0	1688	73.8	0.002 †	1583	66.1	1128	63.2	0.429
	absent	2221	21.8	583	25.5		785	32.8	646	36.2	
	missing	118	1.2	15	0.7		28	1.2	11	0.6	
Parks/foot paths suitable for exercise/walking	present	7502	73.7	1589	69.5	<0.001 †	1507	62.9	1040	58.3	0.004 †
	absent	2564	25.2	683	29.9		855	35.7	725	40.6	
	missing	117	1.2	14	0.6		34	1.4	20	1.1	

Table 2. *Cont.*

		GDS Score of <5 (n = 12,469)					GDS Score of ≥5 (n = 4181)				
		Good (n = 10,183)		Poor (n = 2286)			Good (n = 2396)		Poor (n = 1785)		
		n	%	n	%	*p* *	n	%	n	%	*p* *
Locations difficult for walking (hills or steps)	present	3859	37.9	924	40.4	0.047	1080	45.1	798	44.7	0.972
	absent	6231	61.2	1347	58.9		1292	53.9	969	54.3	
	missing	93	0.9	15	0.7		24	1.0	18	1.0	
Roads/crossroads with risk of traffic accidents	present	6518	64.0	1545	67.6	0.004 †	1634	68.2	1247	69.9	0.454
	absent	3556	34.9	723	31.6		735	30.7	516	28.9	
	missing	109	1.1	18	0.8		27	1.1	22	1.2	
Fascinating views or buildings	present	4329	42.5	874	38.2	<0.001 †	1583	66.1	1128	63.2	0.051
	absent	5701	56.0	1383	60.5		785	32.8	646	36.2	
	missing	153	1.5	29	1.3		28	1.2	11	0.6	
Shops or facilities selling fresh fruits & vegetables	present	7844	77.0	1688	73.8	<0.001 †	704	29.4	460	25.8	0.017
	absent	2221	21.8	583	25.5		1658	69.2	1303	73.0	
	missing	118	1.2	15	0.7		34	1.4	22	1.2	
Dangerous places for walking alone at night	present	7844	77.0	1688	73.8	0.017 †	1583	66.1	1128	63.2	0.643
	absent	2221	21.8	583	25.5		785	32.8	646	36.2	
	missing	118	1.2	15	0.7		28	1.2	11	0.6	
Houses or facilities where you feel free to drop in	present	4575	44.9	877	38.4	<0.001 †	704	29.4	460	25.8	0.028 †
	absent	5479	53.8	1379	60.3		1658	69.2	1303	73.0	
	missing	129	1.3	30	1.3		34	1.4	22	1.2	

* Chi-square test. † Scheffe's multiple comparison procedure; Significant difference was found between GDS score of <5 age:65–69 and 70–74 ($p = 0.008$), 65–69 and≥ 85 ($p < 0.001$), 70–74 and ≥85 ($p = 0.001$), living alone: no and yes ($p = 0.044$), Self-rated health: fair and poor ($p < 0.001$), poor and missing ($p < 0.001$),Job: having and no ($p < 0.001$), Equivalent income: <200 million yen and 200–400 million yen ($p = 0.015$), <200 million yen and ≥400 million yen ($p < 0.001$), 200–400 million yen and ≥400 million yen ($p = 0.044$), Walking time: <60min and ≥60min ($p < 0.001$), Treatment: yes and no ($p < 0.001$),no and missing ($p = 0.041$), Community trus: t very and slightly ($p < 0.001$), slightly and missing ($p = 0.001$), Norms of reciprocity: very and slightly ($p < 0.001$), slightly and missing ($p = 0.005$), Community attachment: very and slightly ($p < 0.001$),very and missing ($p = 0.037$), slightly and missing ($p < 0.001$), Receive instrumental support: no and any one ($p = 0.025$),any one and missing ($p = 0.008$), Locations with graffiti or garbage: present and absent ($p = 0.003$), Parks/foot paths suitable for exercise/walking: present and absent ($p < 0.001$), absent and missing ($p = 0.011$), Roads/crossroads with risk of traffic accidents: present and absent ($p = 0.008$), Fascinating views or buildings: present and absent ($p = 0.001$), Shops or facilities selling fresh fruits & vegetables: present and absent ($p = 0.001$), absent and missing ($p = 0.021$), Dangerous places for Walking: alone at night: present and absent ($p = 0.019$), Houses or facilities where you feel free to drop in: present and absent ($p < 0.001$) GDS score of ≥5 Self-rated health: fair and poor ($p < 0.001$), Community trust: very and slightly ($p < 0.001$), slightly and missing ($p = 0.030$), Norms of reciprocity: very and slightly ($p < 0.001$), slightly and missing ($p = 0.011$), Receive emotional support: very and slightly ($p = 0.001$), slightly and missing ($p = 0.024$), Receive instrumental suppor: t no and any one ($p = 0.001$), Parks/foot paths suitable for exercise/walking: present and absent ($p = 0.001$), Houses or facilities where you feel free to drop in: present and absent ($p = 0.032$).

3.2. Variety of Sleep Quality among the Neighborhood Level

The percentage of poor sleepers ranged from 9.0% to 47.0% among the 568 school districts. There was significant variation in sleep quality between communities: community-level variance was 0.00045 in whole respondents (Model 1 in Table 3) and 0.00074 in non-depressive respondents (Model 1 in Table 4). However, there was no significant variation between communities for depressive respondents; community-level variance was 4.6×10^{-21} (Model 1 in Table 5). The calculated proportional changes in variance (PCV) are shown in each table, which indicate community-level variance due to neighborhood social capital or objective built environment. PCV values are not shown in Table 5 because community-level variance was almost zero for depressive respondents.

Table 3. Results of the multi-level Poisson regression analysis to study the association between neighborhood environment and sleep quality whole participants.

		Model 1	Model 2		Model 3			Model 4		
		PR	95% CI		PR	95% CI		PR	95% CI	
Individual factors										
Depressive status	GDS score of <5	ref								
	GDS score of ≥5	1.93	1.80	2.07	1.93	1.80	2.07	1.92	1.79	2.06
Age (years)	65–69	ref								
	70–74	0.96	0.89	1.04	0.96	0.89	1.04	0.96	0.89	1.04
	75–79	0.82	0.75	0.90	0.82	0.75	0.90	0.82	0.75	0.90
	80–84	0.74	0.66	0.83	0.74	0.66	0.84	0.75	0.66	0.84
	≥85	0.68	0.58	0.80	0.68	0.58	0.80	0.69	0.59	0.80
Sex	male	ref								
	female	1.12	1.05	1.19	1.12	1.05	1.19	1.12	1.05	1.19
Living alone	no	ref								
	yes	1.15	1.05	1.26	1.15	1.04	1.26	1.14	1.04	1.26
Self-rated health	fair	ref								
	poor	1.67	1.55	1.80	1.67	1.55	1.81	1.67	1.55	1.81
Equivalent income (million yen)	<200	ref								
	200–400	0.95	0.88	1.02	0.94	0.88	1.01	0.94	0.88	1.01
	≥400	0.83	0.74	0.94	0.83	0.73	0.94	0.83	0.73	0.94
Job	yes	ref								
	no	1.11	1.02	1.21	1.11	1.02	1.21	1.11	1.02	1.20
Education (years)	<6	ref								
	6–9	0.94	0.76	1.18	0.94	0.75	1.17	0.94	0.75	1.17
	10–12	0.94	0.75	1.17	0.93	0.74	1.16	0.93	0.74	1.16
	≥13	0.94	0.75	1.19	0.93	0.74	1.18	0.93	0.74	1.18
	other	1.25	0.81	1.92	1.24	0.81	1.90	1.24	0.81	1.90
Walking time (min)	<60	ref								
	≥60	0.91	0.85	0.98	0.91	0.85	0.98	0.91	0.85	0.98
Treatment	yes	ref								
	no	0.87	0.80	0.94	0.87	0.80	0.94	0.87	0.80	0.94
Social environment (Social Capital)										
Civic participant	every 10% increase				1.14	0.91	1.44			

Table 3. *Cont.*

		Model 1			Model 2			Model 3			Model 4		
					PR	95% CI		PR	95% CI		PR	95% CI	
Social cohesion	every 10% increase							1.00	0.80	1.25			
Reciprocity	every 10% increase							0.83	0.48	1.43			
Physical environment													
No location with graffiti or garbage	every 10% increase										0.83	0.51	1.33
Parks or foot paths suitable for exercise or walking	every 10% increase										1.00	0.72	1.37
No difficult locations for walking such as hills or steps	every 10% increase										0.84	0.68	1.04
No risky roads or crossroads with risk of traffic accidents	every 10% increase										0.83	0.51	1.35
Fascinating views or buildings	every 10% increase										0.99	0.73	1.33
Shops or facilities selling fresh fruits and vegetables	every 10% increase										1.09	0.82	1.45
No dangerous places for walking alone at night	every 10% increase										1.33	0.79	2.23
Houses or facilities where you feel free to drop in	every 10% increase										0.59	0.36	0.95
Intercept		0.27	0.27	0.28	0.03	-0.49	0.11	0.25	-0.09	0.60	0.14	0.02	0.26
Random effects													
Community-level variance (SE)		0.0004	(−0.0003)		0.0002	(−0.0003)		0.0001	(−0.0003)		2.97×10^{-11}	(5.5×10^{-11})	
PCV					0.50			0.75			0.99		

PR = prevalence ratio; 95% CI = 95% confidence interval. PCV = proportional change in variance. Multi-level Poisson regression analysis: Model 1 is the null model; Model 2 is individual-level variables; Model 3 was adjusted for social, capital, and individual-level variables; Model 4 was adjusted for neighborhood, environment, and individual-level variables.

Table 4. Results of the multi-level Poisson regression analysis to study the association between neighborhood environment and sleep quality in non-depressive participants (Geriatric Depression Scale Score of <5).

		Model 1	Model 2		Model 3			Model 4		
		PR	95% CI		PR	95% CI		PR	95% CI	
Individual factors										
Age (years)	65–69	ref								
	70–74	0.94	0.85	1.04	0.96	0.87	1.07	0.94	0.85	1.05
	75–79	0.75	0.66	0.85	0.77	0.68	0.87	0.75	0.66	0.85
	80–84	0.71	0.6	0.83	0.74	0.63	0.87	0.71	0.6	0.84
	≥85	0.52	0.4	0.68	0.55	0.42	0.72	0.52	0.4	0.69
Sex	male	ref								
	female	1.16	1.06	1.27	1.15	1.05	1.26	1.17	1.07	1.28
Living alone	no	ref								
	yes	1.16	1.01	1.33	1.14	0.99	1.31	1.15	1	1.32
Self-rated health	fair	ref								
	poor	1.97	1.76	2.2	1.93	1.73	2.16	1.97	1.76	2.2
Equivalent income (million yen)	<200	ref								
	200–400	0.92	0.84	1.01	0.92	0.83	1.01	0.92	0.83	1.01
	≥400	0.82	0.71	0.95	0.82	0.71	0.96	0.82	0.7	0.95
Job	yes	ref								
	no	1.16	1.04	1.29	1.13	1.02	1.27	1.15	1.03	1.28
Education (years)	<6	ref								
	6–9	0.84	0.6	1.16	1	0.91	1.09	0.82	0.59	1.14
	10–12	0.84	0.6	1.17	1.06	0.57	1.97	0.82	0.59	1.14
	≥13	0.81	0.58	1.14	0.88	0.8	0.97	0.79	0.56	1.11
	other	0.96	0.49	1.87	0.83	0.75	0.93	0.96	0.49	1.88
Walking time (min)	<60	ref								
	≥60	0.88	0.8	0.96	0.88	0.8	0.97	0.88	0.8	0.96
Treatment	yes	ref								
	no	0.84	0.76	0.94	0.83	0.75	0.93	0.84	0.76	0.94
Social environment (Social Capital)										
Civic participant	every 10% increase				1.21	0.88	1.67			
Social cohesion	every 10% increase				1.04	0.77	1.4			
Reciprocity	every 10% increase				0.96	0.44	2.1			
Physical environment										
No location with graffiti or garbage	every 10% increase							0.68	0.36	1.29

Table 4. *Cont.*

		Model 1		Model 2			Model 3			Model 4		
				PR	95% CI		PR	95% CI		PR	95% CI	
Parks or foot paths suitable for exercise or walking	every 10% increase									0.99	0.64	1.54
No difficult locations for walking such as hills or steps	every 10% increase									0.75	0.56	0.99
No risky roads or crossroads with risk of traffic accidents	every 10% increase									0.92	0.47	1.79
Fascinating views or buildings	every 10% increase									0.98	0.66	1.47
Shops or facilities selling fresh fruits and vegetables	every 10% increase									1.21	0.82	1.78
No dangerous places for walking alone at night	every 10% increase									1.41	0.7	2.86
Houses or facilities where you feel free to drop in	every 10% increase									0.51	0.26	0.98
Intercept	0.2	0.19	0.21	0.12	0.07	0.19	0.08	0.01	0.66	0.14	0.66	0.34
Random effects												
Community-level variance (SE)		0.00074	(0.00038)	0.06	(0.00061)	0.00045	0.00055	(0.00044)		0.00025	(0.00041)	
PCV				0.176			0.257			0.662		

PR = prevalence ratio; 95% CI = 95% confidence interval. PCV = proportional change in variance. Multi-level Poisson regression analysis: Model 1 is the null model; Model 2 is individual-level variables; Model 3 was adjusted for social, capital, and individual-level variables; Model 4 was adjusted for neighborhood, environment, and individual-level variables.

Table 5. Results of the multilevel Poisson regression analysis to study the association between neighborhood environment and sleep quality in depressive participants (Geriatric Depression Scale score of ≥5).

		Model 1	Model 2		Model 3			Model 4		
		PR	95% CI		PR	95% CI		PR	95% CI	
Individual-level										
Age (years)	65–69	ref								
	70–74	0.99	0.87	1.12	1	0.88	1.13	0.99	0.87	1.12
	75–79	0.92	0.8	1.05	0.94	0.82	1.09	0.92	0.8	1.06
	80–84	0.79	0.67	0.94	0.83	0.7	0.99	0.8	0.67	0.95
	≥85	0.83	0.68	1.01	0.86	0.7	1.06	0.84	0.68	1.02
Sex	male	ref								
	female	1.06	0.96	1.17	1.06	0.96	1.16	1.06	0.96	1.17
Living alone	no	ref								
	yes	1.14	1	1.29	1.11	0.97	1.26	1.14	1	1.29
Self-rated health	fair	ref								
	poor	1.49	1.35	1.65	1.46	1.32	1.62	1.49	1.35	1.65
Equivalent income (million yen)	<200	ref								
	200–400	0.97	0.87	1.09	0.99	0.88	1.11	0.97	0.87	1.08
	≥400	0.86	0.69	1.08	0.89	0.71	1.11	0.86	0.69	1.07
Job	have	ref								
	no	1.04	0.91	1.19	1.04	0.91	1.19	1.04	0.91	1.19
Education (years)	<6	ref								
	6–9	1.07	0.79	1.44	1.11	0.82	1.5	1.07	0.79	1.44
	10–12	1.05	0.77	1.42	1.09	0.8	1.49	1.05	0.77	1.42
	≥13	1.12	0.82	1.54	1.15	0.84	1.6	1.12	0.82	1.55
	other	1.54	0.88	2.69	1.63	0.92	2.89	1.53	0.88	2.67
Walking time (min)	<60	ref								
	≥60	0.97	0.86	1.08	0.96	0.86	1.08	0.97	0.86	1.09
Treatment	yes	ref								
	no	0.92	0.81	1.06	0.92	0.8	1.05	0.92	0.81	1.06
Social environment (Social Capital)										
Civic participation	every 10% increase				0.98	0.7	1.38			
Social cohesion	every 10% increase				1.05	0.76	1.47			
Reciprocity	every 10% increase				0.83	0.38	1.83			
Physical environment										
No location with graffiti or garbage	every 10% increase							1	0.49	2.04
Parks or foot paths suitable for exercise or walking	every 10% increase							1	0.62	1.61
No difficult locations for walking such as hills or steps	every 10% increase							0.99	0.73	1.35

Table 5. *Cont.*

		Model 1		Model 2			Model 3			Model 4		
				PR	95% CI		PR	95% CI		PR	95% CI	
No risky roads or crossroads with risk of traffic accidents	every 10% increase									0.75	0.36	1.55
Fascinating views or buildings	every 10% increase									1.01	0.64	1.57
Shops or facilities selling fresh fruits and vegetables	every 10% increase									0.96	0.63	1.45
No dangerous places for walking alone at night	every 10% increase									1.17	0.54	2.53
Houses or facilities where you feel free to drop in	every 10% increase									0.72	0.35	1.47
Intercept		0.47	0.45	0.25	0.15	0.43	0.28	0.03	2.41	0.31	0.14	0.67
Random effects												
Community-level variance (SE)		4.6×10^{-21}	(1.09×10^{-20})	9.22×10^{-18}	(1.79×10^{-17})		2.04×10^{-19}	(4.87×10^{-19})		(1.6×10^{-11})	(3.9×10^{-19})	
PCV				-			-			-		

PR = prevalence ratio; 95% CI = 95% confidence interval. PCV = proportional change in variance. Multilevel Poisson regression analysis: Model 1 is the null model; Model 2 is individual-level variables; Model 3 was adjusted for social, capital, and individual-level variables; Model 4 was adjusted for neighborhood environment- and individual-level variables.

3.3. Individual and Neighborhood Factors Associated with Sleep Quality

For some of the neighborhood-level variables, there were significant interactions with depressive status on sleep quality.

3.3.1. Whole Respondents

Model 2 revealed that higher GDS score of ≥5 (depressive) had poor sleep quality (PR of poor sleep: 1.93, 95% CI: 1.80–2.07) and older participants tended to have better sleep quality than younger participants (PR of poor sleep in those aged 75–79 years: 0.82, 95% CI: 0.75–0.90; 80–84 years: 0.74, 95% CI: 0.66–0.83; and ≥85 years: 0.68, 95% CI: 0.58–0.80; each compared to those aged 65–69 years) (Table 3). In addition, being female, living alone, poor self-rated health, and not working were significantly associated with poor sleep (each PR was 1.12, 95% CI: 1.05–1.19 [against being male]; 1.15, 95% CI: 1.05–1.26 [against not living alone]; 1.67, 95% CI: 1.55–1.80 [against good self-rated health]; and 1.11, 95% CI: 1.02–1.21 [against working]). A higher equivalent household income was significantly associated with good sleep (PR for ≥4.00 million yen: 0.83, 95% CI: 0.74–0.94 [compared to <2.00 million]); however, education attainment was not associated with sleep quality. Longer walking time (>60 min) was associated with good sleep (PR: 0.91, 95% CI: 0.85–0.98 [compared to <60 min]).

Model 3 revealed no significant associations between neighborhood-level social capital in any of the three components (civic participation, social cohesion, or reciprocity) and sleep quality. However, regarding the physical environment, fewer difficult locations for walking such as steps or slopes was marginally associated with fewer poor sleepers (PR = 0.84, 95% CI: 0.68–1.04) according to model 4. Similarly, more places (houses or facilities) where participants feel free to drop in were associated with fewer poor sleepers (PR = 0.59, 95% CI: 0.80–0.94).

3.3.2. Non-Depressive Respondents (GDS Score of <5)

Model 2 revealed that older participants tended to have better sleep quality than younger participants (PR of poor sleep in those aged 75–79 years: 0.75, 95% CI:0.66–0.85; 80–84 years: 0.71, 95% CI: 0.6–0.83; and ≥85 years: 0.52, 95% CI: 0.4–0.68; each compared to those aged 65–69 years) (Table 4). In addition, being female, living alone, poor self-rated health, and not working were significantly associated with poor sleep (each PR was 1.16, 95% CI: 1.06–1.27 [against being male]; 1.16, 95% CI: 1.01–1.33 [against not living alone]; 1.97, 95% CI: 1.76–2.20 [against good self-rated health]; and 1.16, 95% CI: 1.04–1.29 [against working]). A higher equivalent household income was significantly associated with good sleep (PR for ≥4.00 million yen: 0.82, 95% CI: 0.71–0.95 [compared to <2.00 million]); however, education attainment was not associated with sleep quality. Longer walking time (>60 min) was associated with good sleep (PR: 0.88, 95% CI: 0.8–0.96 [compared to <60 min]).

Model 3 revealed no significant associations between neighborhood-level social capital in any of the three components (civic participation, social cohesion, or reciprocity) and sleep quality. However, regarding the physical environment, fewer difficult locations for walking such as steps or slopes was associated with fewer poor sleepers (PR = 0.75, 95% CI: 0.56–0.99) according to model 4. Similarly, more places (houses or facilities) where participants feel free to drop in were associated with fewer poor sleepers (PR = 0.51, 95% CI: 0.26–0.98).

3.3.3. Depressive Respondents (GDS Score of ≥5)

In the depressive respondents, older participants tended to have better sleep quality than younger participants (PR of poor sleep in those aged 80–84 years: 0.79, 95% CI: 0.67–0.94; and ≥85 years: 0.83, 95% CI: 0.68–1.01; each compared to those aged 65–69 years) (Table 5). Sex differences were not observed with regard to sleep quality. Living alone was marginally associated and poor self-rated health was significantly associated with poor sleep (each PR was 1.14, 95% CI: 1–1.29 [against not living alone]; 1.49, 95% CI: 1.35–1.65 [against good self-rated health]). Neither equivalent household

income nor education attainment was associated with sleep quality. Walking time and the existence of any diseases were not associated with sleep quality.

Model 3 revealed no significant associations between neighborhood-level social capital in any of the three components (civic participation, social cohesion, or reciprocity) and sleep quality, as was the case in the non-depressive respondents; Model 4 revealed there was no association between any physical environment factors and sleep quality.

4. Discussion

In this study, we investigated the associations between sleep quality and factors at the individual and neighborhood levels, using data from the JAGES 2010 study of older people in 31 Japanese municipalities. The analysis utilized large-scale data from over 100,000 survey respondents. We found that older people slept better if they lived in environments where there were places (houses or facilities) that they felt free to drop in. Because sleep quality is closely associated with depression, [4–6] we stratified the analysis by depressive status after analyzing the whole dataset. We found that non-depressive older people slept better if they lived in environments with few hills or steps and where there were places (houses or facilities) that they felt free to drop in. For depressive older people, these associations were not evident. The associations between individual-level factors and sleep quality were very similar to those described in previous studies, with living alone, poor self-rated health, low income, and unemployment being associated with poor sleep quality in older people [31,32].

The existence of places (houses or facilities) where older people feel free to drop in is believed to encourage them to go outside [33]. Going out not only increases their activity level but enables older people to engage in communication, such as enjoying conversations at these facilities when they drop in. It is possible that a satisfying lifestyle during the day may affect sleep quality.

It has previously been reported that physical activity increases significantly in a good neighborhood environment [34]. A residential environment with few hills or steps may make it easier for older people to go for walks [35]. A walkable environment is more likely to encourage older people to go outside, for example, to shop for daily necessities or to go for a walk or take other forms of exercise [36]. Making it easier to go outside may increase physical exercise, resulting in an appropriate level of fatigue and leading to good-quality sleep [21,37,38]. Although the existence of parks or foot paths might also promote physical activity, there is no significant effect in this dataset. One possible reason for this lack of effect is that people need to intentionally go to a park or foot path for exercising. In contrast, a residential environment with few hills or steps directly and unconsciously affects their habit of daily exercise. Such circumstances that promote physical activity without clear intention may sometimes successfully achieve the goal.

However, no such significant association with environmental factors was evident in depressive respondents in the stratified analysis. The absence of an association with physical environmental factors in depressive individuals may be because these individuals tend to isolate themselves and do not go out [39], making them less likely to be affected by the physical environment of the neighborhood. This might be a reasonable result.

According to the 2019 White Paper on the Aging Society (published by the Cabinet Office) [40], the Japanese population is currently aging rapidly, with 27.7% aged ≥65 years, the highest in any developed country. By 2065, this proportion is projected to reach 38.4%, with approximately one in every 2.6 people aged ≥65 years. According to the 2016 National Health and Nutrition Survey in Japan, 48.4% of all households included an older person aged ≥65 years, of which >50% were households consisting only of older people [41]. Even in households that include younger members, older people are often left by themselves during the day, and an environment in which they can easily go outside and that contains venues where they can communicate with others during the day will be one that is reassuring for them. Being able to spend time in a reassuring environment during the day may result in good quality sleep. Non-depressive individuals accounted for 75% of the respondents in this study.

We believe that it is necessary to create an environment in which they can sleep better based on our study results.

Sleep problems are closely associated with individual-level factors such as individual lifestyle habits, social status, and income [16,17]. The results of our study suggested that in addition to support with these individual factors, approaching environmental factors from further upstream at the neighborhood level from the perspective of social determinants of health may also help to improve the sleep quality of local residents.

Because we considered that the local environment includes the human environment as well as the physical environment, we conducted an analysis of the former in terms of so-called "social capital." The positive effect of social capital on health has been well described in previous studies [42,43]. Putnam [44] defined social capital as trust, norms, and networks that facilitate action and cooperation for mutual benefit. In this study, we did not identify a significant association between social capital in the local community and individual sleep quality. In the Multi-Ethnic Study of Atherosclerosis (MASE) carried out in the United States, higher levels of neighborhood social cohesion were associated with longer sleep duration [26]. Although this was not confirmed by a multilevel analysis, a survey by De Santis et al. [45] of 1406 individuals aged 45–84 years in six United States cities found that a lower level of social cohesion was significantly associated with shorter sleep duration. However, a study of local residents in South Korea and Taiwan by Nomura et al. [18] did not identify any associations between social capital and sleep. Few studies have addressed the association between these two factors, and only a limited number have applied multilevel analyses in particular. Further studies on such associations are required in the future.

It is known that health disparity is influenced by environmental differences. For instance, there is a two-year shorter life expectancy in the Adachi ward of Tokyo compared to the average life span in the entire city of Tokyo, based on 2010 data. An intervention to change diet habits in the Adachi ward by increasing accessibility to fresh vegetables, reduced this life span gap due to a decrease in the prevalence of diabetes. Similarly, environmental changes that increase opportunities for walking and provide multiple destinations might improve the quality of sleep in older adults.

Especially for older people who spend most of their time in residential neighborhoods, improving the environment is an important measure. In Japan, a movement is underway to open salons in local neighborhoods to encourage older people to go out [21,46]. Interventions with the objective of improving access to restaurants, small shops, and other non-residential facilities in the community are also believed to help maintain older people's physical activity levels and prevent their health from deteriorating by encouraging them to leave the house on a regular basis [47,48]. Our results suggest that increasing the number of places in residential neighborhoods where older people feel free to drop in and improving the physical environment might improve their sleep quality.

Individual-level factors associated with sleep quality in non-depressive respondents included female sex, living alone, poor self-rated health, low income, unemployment, short walking time, and undergoing medical treatment for disease, all of which increased the risk of poor sleep quality. These results were consistent with those of previous studies, which have identified associations between sleep quality and individual-level factors including sex, income, and household composition [45]. In this study, non-depressive respondents with lower incomes slept more poorly, a finding consistent with those of previous studies [49,50]. The association between income and health is well known. Individuals with lower incomes have been found to be at higher risk of lifestyle-related diseases and depression [27,51–54], and the same may be true for sleep quality. Respondents who were unemployed also had significantly poorer quality sleep. After retirement, some people may find that withdrawal from the front line of society leaves them with feelings of exclusion and isolation, leaving them unable to find meaning in life. It is possible that an unfocused, inactive lifestyle may have an adverse effect on sleep quality.

In contrast, the only two factors significantly associated with sleep quality in depressive respondents were young age and poor self-rated health. Although there were significant associations

between sleep quality and a large number of individual-level factors including sex, living alone, income, employment, walking time, and medical treatment for disease in non-depressive respondents, very few such significant associations were present in depressive respondents. Although no similar results have previously been published, as depression and sleep are closely related [55,56], the effect of the other factors may have been relatively smaller and thus evident in the analysis results.

An association between living alone and poor sleep quality has also been demonstrated in a previous study of older people living in a Chinese city [11]. The number of single-person households is projected to further increase in future. Sleep support for older people living alone will become an important issue. In this study, we found that a higher proportion of older respondents reported good-quality sleep. Previous studies have found that sleep quality deteriorates with age [11]. One possible reason for this discrepancy may be that our study participants were all aged ≥65 years, and our results therefore reflect a comparison between older people. Our study also did not include any older people registered as requiring long-term care. The particular elderly age groups in our study may therefore be comprised of older people who have maintained their health into old age. The fact that sleep quality improved with age in our study may thus have been due to the effect of "survival bias." We did not identify any association between education attainments and sleep quality. A study of self-care activities by older people in the United States [57], as well as another of older people living in a rural community in South Korea [58], found that the lower the level of education attainment, the higher the rate of insomnia. However, an Iranian study of sleep quality in healthy older people found no association between the prevalence of sleep disorder and the highest level of educational attainment [59]. Thus, the association between education attainment and sleep quality is inconsistent. Japanese people now aged ≥80 years belong to the generation that experienced the war during their school years, and their life courses encompass experiences that differ from those of other generations [60]. This may be the reason for the absence of any association between the highest level of education attainment and sleep quality in our participants. Further, it is not a general rule that people with higher education attainment sleep better.

Reduced sleep quality in older people not only leads to lifestyle-related disorders such as hypertension and diabetes as well as depression and other mental disorders, but also reduces the quality of life (QOL) and is a contributing factor to the need for long-term care [61–63]. Measures to improve sleep are also needed in order to maintain the QOL of older individuals.

Strengths and Limitations of the Study

The JAGES study data used in our analysis have provided numerous findings that might form the basis for strategies to help prevent older people from needing long-term care. Examples include the associations between social capital and neighborhood walkability [34], childhood socioeconomic status and fruit and vegetable intake, [64] and eating alone and depression [24]. This study yielded novel findings from the perspective of helping people to sleep better at the neighborhood level.

However, this study has several limitations. First, since this was a cross sectional study, we were not able to infer causality. Second, the assessment of sleep quality in this study was subjective; to further improve the reliability of our findings, it may be necessary to objectively evaluate the quality of sleep. Third, we did not consider comorbidities, which may be a confounder. The main limitation in our study was the reliance on self-reports of sleep difficulties. However, the self-reported sleep difficulties may in any case be relevant to their well-being. Fourth, the present analysis was based on data from 2010; since then, the circumstances in parts of Japan have changed drastically, particularly after the East Japan Great Earthquake in 2011. Despite this limitation, the findings obtained from the cross-sectional analysis in 2010 are still relevant to the development of current public health policy.

5. Conclusions

Sleep problems are closely associated with individual-level factors such as individual lifestyle habits, income, and employment. Our results suggested that in addition to these individual factors,

approaching environmental factors from further upstream at the neighborhood level from the perspective of social determinants of health may also help to improve the sleep quality of local residents.

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Does community-level social capital mitigate the impact of widowhood & living alone on depressive symptoms?: A prospective, multi-level study

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Highlights

•Recently widowed men living alone shows severe depressive symptoms.
•Social capital shows contextual associations with depressive symptoms.
•Lower depressive symptoms among people in communities rich in civic participation.
•Recently widowed men living alone benefit more from community civic participation.

Abstract

Widowhood and living alone are linked to increased risk of depression. We examined prospectively whether community-level social capital can mitigate the adverse impact of widowhood and living alone on depressive symptoms. We used data of the Japan Gerontological Evaluation Study of functionally independent adults aged 65 years or older. Three waves of surveys were collected in 2010, 2013 and 2016. We conducted gender-stratified multilevel linear regression to examine the moderating effects of community-level social capital on depressive symptoms (as assessed by the 15-point Geriatric Depression Scale) associated with widowhood and living alone. Widowhood

in the past 12 months in combination with living alone was associated with a marked worsening in depressive symptoms among men (beta coefficient = 1.67; 95% confidence interval: 1.38, 1.95). Community-level civic participation, but not social cohesion or reciprocity, was associated with lower depressive symptoms in men and women. In addition, community-level civic participation moderated the association between depressive symptoms and recent widowhood/living alone among men (coefficient per 1 standard deviation = −0.30; 95% confidence interval: −0.59, −0.02). We found no significant effect modification of community-level social capital on depressive symptoms associated with widowhood and living alone among women. Communities with greater civic participation appear to mitigate the onset of depressive symptoms among recently widowed men living alone. Promotion of community activities might be an effective community-level intervention to promote mental health in this vulnerable group.

Keywords

Widowhood; Living alone; Gender; Social capital; Social participation

Can social capital moderate the impact of widowhood on depressive symptoms? A fixed-effects longitudinal analysis

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Abstract

Objectives

Widowhood is associated with increased risks of depression in the surviving spouse. We examined whether an increase in individual-level social capital mitigates the adverse impact of widowhood on depressive symptoms.

Methods

We used data from the 2013/2016 waves of the Japan Gerontological Evaluation Study of functionally independent adults aged 65 years or older (men: *n* = 20,853; women: *n* =16,858). Fixed-effects regression was applied to examine the potential buffering effects of changes in social capital on changes in depressive symptoms following widowhood among married people living with their spouse and/or others at baseline.

Results

Widowhood had a deleterious impact on depressive symptoms particularly among men who ended up living alone following their spouse's death. Fixed-effects models revealed that an increase in informal socializing and social participation might buffer the effects of spousal bereavement on depressive symptoms among men who became widowed during the first two years of follow-up and ended up living alone.

Discussion

An increase in structural social capital may mitigate the impact of spousal bereavement on depressive symptoms. However, the associations vary by gender, living arrangement, and time since widowhood. Intensive efforts should be directed toward connecting the vulnerable group, widowed men living alone, to sources of social capital.

Keywords: Widowhood; living alone; social participation; depression; depressive symptoms

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Can Online Communication Prevent Depression Among Older People? A Longitudinal Analysis

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Abstract

Evidence on the association between internet usage and incidence of depression remains mixed. We examined the associations between different categories of internet usage and developing clinical depression. We used data from the 2013 and 2016 waves of the Japan Gerontological Evaluation Study (JAGES) comprising 12,333 physically and cognitively independent adults aged ≥65 years. Participants were engaged in seven categories of internet usage: communication with friends/family, social media, information collection about health/medicine, searching for medical facilities, purchase of drugs and vitamins, shopping, and banking. We found that internet use for communication had a protective influence on the probability of developing clinical depression defined as the Geriatric Depression Scale scores ≥5 or self-reported diagnosed depression. Our findings support the role of online communication with friends/family in preventing clinical depression among older people. Online communication could be particularly useful in the COVID-19 crisis because many families are geographically dispersed and/or socially distanced.

Keywords

depression, internet use, online communication, social interaction, social distancing, COVID-19

Introduction

Late-life depression is a serious public health issue, associated with high mortality, morbidity, and decreased physical, cognitive, and social function (Blazer, 2003; Fiske et al., 2009; Wei et al., 2019). The proportion of the global population with depression in 2015 was estimated at more than 7% among females aged 65 to 79 years, and above 5% among males (World Health Organization, 2017). In addition, late-life depression often remains undetected among community-dwelling people. Among older people aged 50 years or older, bereavement, disability, prior depression, and female gender are important risk factors for depression (Cole & Dendukuri, 2003). Modifiable protective factors that have been shown to reduce the incidence of depression include the provision of emotional support and promoting social interactions (Berkman et al., 2014; Cole & Dendukuri, 2003; Gariepy et al., 2016).

A growing number of older adults, defined as people aged 65 years or older, are connected to the internet today. For example, the proportion of internet users aged 65 years or older in the United States reached 73% in 2019 (Pew Research Center, 2019). Similar trends are found in Japan: The proportion of internet users among Japanese people aged 65 years or older has reached 63.6% in 2019 (Ministry of Internal Affairs and Communications, 2020). The internet has changed daily life in several ways. It enables people to communicate with friends and family remotely; to search for useful information easily (e.g., health-related information); to perform instrumental activities such as shopping and banking from home; and especially in the era of the COVID-19 pandemic, to telecommute to work.

Several studies have focused on the role of the internet in alleviating depressive symptoms among older people, but with mixed findings. Cotten et al. (2014) reported that internet

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usage was found to reduce the probability of depression by 33% in a longitudinal study using the data from 2002 to 2008 among retired people over the age of 50 years in the United States. Another longitudinal study using relatively recent data from 2012 to 2015 among Korean adults aged 50 years or older showed that internet use lowered depression, partially mediated by an improvement in social relationship satisfaction (Jun & Kim, 2017). A cross-sectional study conducted in China in 2016 also showed that internet usage was associated with lower depression levels among adults aged 60 years or older (Wang et al., 2019). By contrast, some studies reported no direct association between internet usage and depression. For example, two cross-sectional studies and a longitudinal study conducted between 2008 and 2011 among older people showed no significant association between internet use and depression/depressive symptoms (Elliot et al., 2014; Erickson & Johnson, 2011; Hamer & Stamatakis, 2014). A meta-analysis that retrieved studies that had been published from 2001 to 2012 showed the overall mean weighted effect size of computer and internet interventions for depression was not statistically significant (M. Choi et al., 2012). Another meta-analysis published in 2010 even suggested a small detrimental effect of internet usage on psychological well-being (Huang, 2010), although this study included the general population and age was assessed as a moderator while no significant effect modification was found. It should be pointed out, however, that these negative findings were based on relatively old data. Considering the rapidly increasing availability of the internet among older people, studies using data reflecting current situations are required to examine the role of internet use today.

The inconsistencies across studies of the impacts of internet use on depression may be attributable partly to the challenges of teasing out reverse causality—for example, people with depression/depressive symptoms might be less likely to use the internet. As the existing evidence on the relationship between internet use and depression is mostly based on cross-sectional data, the use of longitudinal data to establish temporality is warranted.

Another explanation is insufficient differentiation between alternative uses of the internet. Although older people use the internet for various purposes, many studies focused on a crude comparison between users versus nonusers. van Boekel et al. (2017) identified four groups of usages in a latent class analysis based on the internet activities among older adults aged 65 years and older in the Netherlands: practical users (engaging in practical and financial activities), minimizers (low-frequency use), maximizers (high-frequency use for various activities, including "chatting, video calling, sending messages."), and social users (engaging in social media and online games). Practical users and maximizers reported higher psychological well-being than minimizers and social users. Szabo et al. (2019) reported that social use (connecting with friends/family) indirectly affected well-being via decreased loneliness and instrumental (e.g., banking) and informational uses (e.g., reading health-related information) indirectly affected well-being via engagement in a wider range of activities. These findings suggest that the impacts of internet use among older people might vary according to purposes, although these studies did not focus on depression. Because of the close and bidirectional relationship between loneliness and depression, online communication might be an effective tool for preventing loneliness and depression in older people (National Academies of Sciences, Engineering, and Medicine, 2020). Especially, during the COVID-19 pandemic, loneliness among older people is a serious problem because of their greater vulnerability to the virus, and hence their greater need to comply with social distancing guidelines (Killgore et al., 2020). Thus, it is of particular interest whether online communication with friends/family can substitute for face-to-face communication particularly for socially isolated people (Ball et al., 2019).

Using data from two waves of the Japan Gerontological Evaluation Study (JAGES) (Kondo, 2016), we assessed specific categories of internet usage among older people defined as aged 65 years or older and how each relates to the incidence of depression longitudinally. We hypothesized that internet use for communication (connecting with friends/family) would be more protectively related to depression than internet use for other purposes such as informational (e.g., health-related information) or instrumental uses (e.g., shopping and banking).

Method

Study Population

We used data from the 2013 and 2016 waves of the JAGES (Kondo, 2016). JAGES is a nationwide population-based gerontological cohort in Japan focusing on the social determinants of health and functional disability. It originated from a smaller survey called the Aichi Gerontological Evaluation Survey (AGES) conducted in Aichi prefecture in 1999. Following the first survey, five waves were conducted in 2003 to 2004, 2006 to 2007, 2010 to 2011, 2013, and 2016. The project was renamed JAGES in 2010 because the survey covered all the major islands in Japan (except for Shikoku). In fact, the surveys conducted in 2013 and 2016 included 137,736 older adults from 30 municipalities and 180,021 older adults from 39 municipalities from rural and urban areas in Japan, respectively (response rate = 71.1% and 70.2%). JAGES is based on questionnaires mailed to older people, defined as aged 65 years or older, who were physically and cognitively independent and were not receiving benefits from the national public long-term care insurance scheme. A census was done for all residents in municipalities with fewer than 5,000 eligible residents, while random sampling was used in large municipalities with 5,000 or more eligible residents. Our data were drawn from respondents

who entered JAGES in the 2013 wave and who were followed up in the 2016 wave (n = 61,267). The 2013 wave of the JAGES data set consisted of five modules. The questions about internet usage were included in one of the five modules. The subsample consisted of 12,333 older adults residing in both rural and urban areas. Among them, our analytic sample was people without clinical depression at baseline, n = 9,199 in the observed (unimputed) data set. Participants were informed that returning the questionnaire indicated their consent to participate.

Clinical Depression

Depressive symptoms were assessed by the short form of the Geriatric Depression Scale (GDS), consisting of 15 questions (GDS-15; score range: 0–15; Cronbach's α = .80; Burke et al., 1991; Nyunt et al., 2009). Higher scores indicate more depressive symptoms. Participants with GDS-15 scores of 5 or greater were considered to be indicative of clinically significant depression (area under the receiver operating characteristic curve = 0.98; Nyunt et al., 2009). Clinical depression was defined as GDS-15 scores ≥5 or self-reported diagnosis of depression.

Internet Usage and Categories of Internet Use

As part of the study, participants indicated whether they used the internet in the past year. In addition, participants were asked to indicate the use for different purposes on a yes/no basis to the following seven categories: (a) communication with friends/family, (b) social media including Facebook and Twitter, (c) information collection about health and medicine, (d) searching for medical facilities, (e) purchase of drugs and vitamins, (f) shopping, and (g) online banking. Participants could select more than one purpose when they engaged in them.

However, communication with friends/family and engagement in social media might overlap for some participants. To address the issue of misclassification, we conducted a sensitivity analysis in which the seven purposes of internet use were collapsed into three categories: (a) social use (communication with friends/family and social media), (b) instrumental use (shopping, purchase of drugs and vitamins, and banking), and (c) informational use (information collection about health and medicine and searching for medical facilities) (Szabo et al., 2019). These categories were analyzed as binary variables: set to 0 if participants answered "No" to any of the items, otherwise set to 1.

Control Variables

We adjusted for a series of demographic factors, physical health conditions, socioeconomic status, and physical social interaction at baseline as potential confounders.

Demographic factors included age and gender because both of them can affect depression levels and the probability of internet use (World Health Organization, 2017).

Physical health is often associated with depression (Hsu, 2009), and people with physical problems might seek information about health problems on the internet or might communicate online with family/friends to share their concerns. Hence, we included the instrumental activities of daily living, which is a validated 13-item self-reported index (score range: 0–13; Koyano et al., 1991), and the number of chronic diseases (diabetes mellitus, cardiovascular diseases, respiratory diseases, stroke, and cancer) as indicators of physical health.

Socioeconomic status has been also associated with depression/depressive symptoms (Gero et al., 2017; Hoogendijk et al., 2014; Shiba et al., 2017) and internet use (Nicole & Eszter, 2009): Thus, educational attainment (<10 or ≥10 years), occupational status (currently employed or unemployed), and annual equivalized income (<2 million yen or ≥2 million yen) were evaluated. Marital status (married or unmarried) and living arrangement (living alone or not) were assessed because of the connections with depression (Honjo et al., 2018; Yan et al., 2011) and their expected effect on internet use.

As an index of physical social interaction, we included the frequency of meeting friends (<once a week; ≥once a week), which was associated with depression (Chao, 2011; Schwarzbach et al., 2014), because people who met their friends frequently might be more likely to use the internet to communicate online with their friends. Some people also might use the internet to compensate for fewer offline interactions (e.g., with families that live far away).

Emotional social support was also associated with depression (Schwarzbach et al., 2014). However, people with no emotional social support might not use the internet for communication because of a lack of resources (i.e., friends/family to talk online) or older people may use the internet as a way to seek such support (Quan-Haase et al., 2017). It was assessed with the following question: "Do you have someone who listens to your concerns and complaints?"

Statistical Analysis

All data were analyzed using STATA 16.0 software (STATA Corp. LLC, College Station, TX, USA). All continuous values were expressed as mean (standard deviation [*SD*]), and categorical variables were reported as percentages in Tables 1 and 2. Pearson's correlation coefficients were calculated among the purposes of internet use. We used logistic regression models to examine how categories of internet use at baseline relate to the onset of clinical depression at the follow-up survey. Our analytic sample in the logistic regression was people without clinical depression at baseline, n = 9,199 in the observed (unimputed) data set. Our basic model was as follows:

Table 1. Characteristics of Internet Nonusers and Users Without Clinical Depression at Baseline.

Variable	Internet nonusers (n = 6,236)	Internet users (n = 2,167)
Developing clinical depression	709 (11.7%)	162 (7.7%)
Age	73.7 (5.6)	71.0 (4.7)
Gender (male)	2,490 (39.9%)	1,339 (61.8%)
Instrumental activities of daily living	11.9 (1.5)	12.2 (1.1)
Number of diseases	0.3 (0.6)	0.3 (0.6)
Unmarried	1,618 (26.5%)	323 (15%)
Living alone	765 (12.9%)	182 (8.5%)
Income (2 million yen)	2,387 (47.0%)	1,411 (71.8%)
Educational attainment (10 years or more)	3,245 (52.6%)	1,852 (85.7%)
Current working	1,419 (25.3%)	640 (30.5%)
Meeting friends ≥once a week	3,342 (55.8%)	1,164 (54.6%)
No emotional social support	205 (3.4%)	65 (3.0%)
Purpose of internet use		
Communication with friends/family		1,129 (52.1%)
Social media		374 (17.3%)
Information collection		903 (41.7%)
Searching for medical facilities		366 (16.9%)
Purchase of drugs and vitamins		68 (3.1%)
Shopping		514 (23.7%)
Banking		387 (17.9%)

Note. Data were missing in 796 people for the variable internet use/purposes among people without clinical depression at baseline (n = 9,199).

$$\begin{aligned}\text{Logit}\Pr[\text{Depression}_{2016} = 1 \mid \text{Internet use}_{2013}, X_{2013}] &= \alpha_0 + \beta_{0*}\text{Internet use}_{2013} \\ &\quad + \beta_1 * X_{2013} + \varepsilon,\end{aligned}$$

where logit probability of clinical depression in 2016 was regressed on internet use in 2013 and a vector of confounding factors in 2013 (X_{2013}). α_0 represents the intercept and ε the residual term. The associations of interest are expressed in the coefficients β_0, or $e^{\beta 0}$ in terms of odds ratio (OR). Seven categories of internet usage were included simultaneously in the logistic model. We did not include product terms in the logistic regression model because we found no evidence of significant effect modification by all confounding variables (age, gender, instrumental activities of daily living, the number of chronic diseases, educational attainment, occupational status, marital status, living arrangement, the frequency of meeting friends, and emotional social support) in the association between internet use for seven purposes and developing clinical depression.

After estimating the logistic regression models, average marginal effects (AMEs) were obtained for clear interpretations as we cannot straightforwardly interpret and compare coefficients/OR as we can in linear regression models (Mood, 2010). AMEs estimate the average of predicted changes in the probability of developing clinical depression for a one-unit increase in a particular variable controlling for other covariates.

We conducted two sensitivity analyses. First, we applied a logistic regression model in which the seven purposes of internet use were collapsed into three categories: social use (communication with friends/family and social media), instrumental use (shopping, purchase of drugs and vitamins, and banking), and informational use (information collection about health and medicine and searching for medical facilities). Second, we conducted linear regression analyses in which the GDS score (continuous variable) in 2016 was used as an outcome variable. We did not exclude people with clinical depression at baseline and included GDS in 2013 to adjust for depressive symptoms at baseline in the sensitivity analysis.

We conducted multiple imputation analyses with the Markov chain Monte Carlo method under the assumption that data were missing at random to address potential bias due to missing data (Rubin, 1997). Data were missing in 9.9% for the variable internet use/purposes, 15.5% for GDS in 2013, and 18.0% for GDS in 2016. The missing data for other variables were less than 10% except for equivalized income (17.3%). We created 20 imputed data sets and combined the effect estimates using Rubin's rule (Rubin, 1996).

Results

Of internet nonusers, 11.7% developed clinical depression, whereas 7.7% of internet users developed clinical depression (Table 1). Older adults who were younger and male and had higher household income and educational attainment were more likely to use the internet. The most common category of internet use was communication with friends/family (52.1%), whereas social media was used by only 17.3% of

Table 2. Characteristics of People Using the Internet for Each Purpose.

	People using the Internet for						
Variable	Communication with friends/ family (n = 1,129)	Social media (n = 374)	Information collection (n = 903)	Searching for medical facilities (n = 366)	Purchase of drugs/ vitamins (n = 68)	Shopping (n = 514)	Banking (n = 387)
Developing clinical depression	71 (6.4%)	32 (8.9%)	76 (8.6%)	38 (10.7%)	8 (12.5%)	42 (8.4%)	28 (7.4%)
Age	71.2 (4.7)	70.6 (4.7)	71.2 (4.7)	71.8 (4.7)	71.1 (4.5)	70.6 (4.6)	71 (4.6)
Gender (male)	700 (62.0%)	272 (72.7%)	549 (60.8%)	217 (59.3%)	39 (57.4%)	305 (59.3%)	307 (79.3%)
Instrumental activities of daily living	12.3 (1)	12.1 (1.3)	12.3 (1)	12.3 (1)	12.2 (1.1)	12.3 (1)	12.2 (1.1)
Number of diseases	0.3 (0.5)	0.3 (0.6)	0.3 (0.6)	0.4 (0.6)	0.3 (0.5)	0.3 (0.6)	0.4 (0.6)
Unmarried	157 (13.9%)	49 (13.2%)	132 (14.7%)	67 (18.5%)	8 (11.8%)	78 (15.2%)	46 (11.9%)
Living alone	98 (8.8%)	36 (9.8%)	82 (9.2%)	41 (11.5%)	4 (6.2%)	34 (6.7%)	24 (6.3%)
Income (2 million yen)	771 (74.5%)	240 (70.2%)	612 (74.2%)	229 (69.4%)	33 (55.9%)	345 (73.6%)	278 (79.0%)
Educational attainment	992 (88.3%)	319 (85.5%)	778 (86.3%)	308 (84.4%)	54 (79.4%)	447 (87.1%)	350 (90.4%)
Current working	319 (29.0%)	137 (37.4%)	266 (30.4%)	91 (25.6%)	16 (24.6%)	145 (29.2%)	119 (31.9%)
Meeting friends ≥ once a week	653 (58.5%)	200 (54.9%)	450 (50.6%)	180 (49.9%)	31 (47.0%)	285 (56.0%)	199 (52.4%)
No emotional social support	28 (2.5%)	20 (5.4%)	22 (2.5%)	11 (3.0%)	1 (1.5%)	13 (2.5%)	16 (4.2%)

Note. Columns show the characteristics of people who used the internet for the seven purposes.

internet users. Men and women used the internet for communication almost equally (men: 52.3%; women: 51.8%). The second most common purpose was information collection about health and medicine (41.7%).

Of internet users for communication purposes, 6.4% developed clinical depression, whereas 7.4% to 12.5% of internet users for other purposes developed clinical depression (Table 2). Internet banking was used mainly by men (79.3%). Other characteristics were roughly comparable among the seven different purposes of usage. We found a moderate association between internet use for information collection about health and medicine and searching for medical facilities (correlation coefficient = .36, $p < .01$), while other bivariate correlations were weak or null (Supplemental Table 1).

The logistic regression models showed that internet use for "communication with friends/family" at baseline was associated with lower odds of developing clinical depression at follow-up (OR: 0.68; 95% confidence interval [CI] = [0.51, 0.89], $p = .005$), whereas any other purposes did not show significant association with clinical depression in the follow-up survey (Table 3, Supplemental Table 2). The AME of internet usage for communication on developing clinical depression was −0.033 (95% CI = [−0.054, −0.013]): The predicted probability of developing clinical depression was on average 3.3% points lower in internet users for communication with friends/family (predicted probability: 11.45% [10.62%–12.29%]) than in people not engaging in communication with friends/family via the internet (predicted probability: 8.11% [6.18%–10.05%]). A sensitivity analysis in which the seven categories of internet use were collapsed into three categories showed that social use (communication with friends/family and social media) at baseline was associated with lower odds of developing clinical depression at follow-up (OR: 0.74; 95% CI = [0.59, 0.94], $p = .01$), whereas instrumental use or informational use did not show significant association with clinical depression in the follow-up survey (Supplemental Table 3).

Another sensitivity analysis applying linear regression model using the GDS as a continuous variable (score range: 0–15) showed the same trend, although the association was marginally significant: Internet users for communication with friends/family showed lower GDS at follow-up by 0.14 after adjusting for GDS and confounding factors at baseline (β: −0.14 [−0.27 to 0.001], $p = .052$; Supplemental Table 4).

Discussion

This study examined distinct purposes for internet use among people aged 65 years or older and how each relates to clinical depression longitudinally. Our findings illustrate that internet use for communication has a protective influence on the probability of developing clinical depression. However, other purposes of internet use showed no protective association with developing clinical depression.

It is of particular interest whether online communication can be an alternative to face-to-face communication for people who do not or cannot interact with others in person. In this study, the frequency of meeting friends was included as an index of physical social interaction. We found

Table 3. Associations Between Internet Usage for Seven Purposes and Developing Clinical Depression at Follow-Up.

Purposes of Internet usage	β [95% CI]	AME [95% CI]	OR [95% CI]
Communication with friends/family	−0.39 [−0.66, −0.12]	−0.033 [−0.054, −0.013]	0.68 [0.51, 0.89]
Social media	0.00 [−0.40, 0.40]	0.00 [−0.038, 0.038]	1.00 [0.67, 1.49]
Information collection	−0.01 [−0.34, 0.32]	−0.001 [−0.032, 0.031]	0.99 [0.71, 1.38]
Searching for medical facilities	0.33 [−0.13, 0.79]	0.036 [−0.018, 0.09]	1.39 [0.88, 2.21]
Purchase of drugs and vitamins	0.15 [−0.78, 1.08]	0.017 [−0.083, 0.117]	1.16 [0.46, 2.94]
Shopping	−0.03 [−0.42, 0.36]	−0.002 [−0.039, 0.034]	0.97 [0.66, 1.44]
Banking	−0.11 [−0.52, 0.30]	−0.01 [−0.047, 0.026]	0.89 [0.59, 1.35]

Note. Controlled for age, gender, instrumental activities of daily living, number of diseases, marital status, living arrangement, equivalized income, educational attainment, current working, the frequency of meeting friends, and emotional social support. AMEs can be interpreted as the higher/lower probability of developing clinical depression than the reference group (internet nonusers). AME = average marginal effects; CI = confidence intervals; OR = odds ratio.

the protective association of online communication with developing clinical depression with no effect modification of confounding variables including the frequency of meeting friends, suggesting that people can benefit from online communication equally, regardless of whether they meet their friends in person. The same might apply for interaction with family members. Although we did not assess the frequency of meeting with family members in this study, living alone would reflect it to some extent: People living alone have less interaction with family members. Our findings suggest that people living alone can benefit from online communication as well as people living with their family.

Although we did not examine pathways linking online communication with the prevention of depression, some of the findings from a longitudinal mediation study by Szabo et al. (2019) might be applicable to our study, that is, virtual interactions with others affected well-being via a decreased sense of loneliness as well as increased social engagement. The findings suggest a role for online communication in creating offline social networks, which is also a plausible pathway linking online communication with the prevention of depression, considering the close relationship between loneliness/social engagement and depression (National Academies of Sciences, Engineering, and Medicine, 2020). However, direct mechanisms, not via offline social activities, may also be involved. For example, video talking with family/friends and online social activities/events might increase the range and diversity of social connections (Barbosa Neves et al., 2019). In the era of COVID-19, the direct effects of online communication need to be investigated urgently.

This study did not show a significant relationship between social media use and developing clinical depression. Social media also provides opportunities to communicate with others, but communication on social media (e.g., posting, reading, and checking messages/pictures) may differ from phone/video talking and sending messages to friends/family. Nevertheless, some participants might engage in both forms of media (phone/video talking as well as social media) to communicate with friends/family. The sensitivity analysis in which communication with friends/family and social media usage were collapsed into a single category of "social use" supported our main finding, that is, online communication might prevent developing depression. However, further studies are required to examine which type of online communication can be effective to prevent depression.

Methods of connecting to the internet (e.g., phone, tablet, and computer) might determine or pose barriers for how people use the internet for communication. For example, if people do not have a smartphone, they would not be able to communicate with friends using apps available only on smartphones. The increasing availability of smartphones may provide more opportunities for older people to communicate with their friends. However, larger screen sizes for tablets and computers might be more suitable for some older adults to text, read, and use apps. Future interventions need to take into consideration what type of devices is appropriate for promoting online communication among older people.

In contrast to some previous findings, informational uses (information collection and searching for medical facilities) and instrumental uses (shopping and banking/brokers) were not associated with developing clinical depression. van Boekel et al. (2017) identified four groups of internet usages in a latent class analysis, and practical users (engaging in practical and financial activities) showed better psychological well-being, although it was a cross-sectional association. Szabo et al. (2019) also reported that instrumental (e.g., banking) and informational uses (e.g., reading health-related information) indirectly affected well-being via volunteering in a wider range of activities in a longitudinal study. There are two explanations for this inconsistency. First, the outcome in the previous studies was well-being but not depression or depressive symptoms. Second, our study measured individual's information collection about health, medicine, and medical facilities in contrast with the study by Szabo et al. (2019) which also measured searching for information about music/entertainment. Online information seeking about things of their interest might encourage people to engage in community activities and volunteering (N. G. Choi & Dinitto, 2013), but it would not be applicable to people seeking information about health-related problems.

Limitations

There are some limitations to this study. First, we could not fully identify the causality of the relationships. Although we excluded people with clinical depression at baseline to deal with reverse causality and adjusted for a series of potential confounders, there may still be unmeasured confounders. Second, we could not measure internet usage and confounding factors between the two study periods. Thus, we had to assume that these variables had remained the same during the time period, although they might have changed over the period. Third, the proportion of internet users among people aged 65 years or older in this study (25.8%) was lower than that reported in the Communications Usage Trend Survey conducted by the Ministry of Internal Affairs and Communications in 2013 (50.5%; Ministry of Internal Affairs and Communications, 2013). The Communications Usage Trend Survey might overestimate the number of internet users because the questionnaires of the survey were mailed and e-mailed, whereas those of JAGES were mailed only. Although the ratio of mail and e-mail in responses to the Communications Usage Trend Survey is not available, it is plausible that internet users are more likely to reply to the questionnaires than internet nonusers, leading to a greater proportion of internet users than reality. However, JAGES might underestimate the proportion of internet users because some mobile phone internet users might be misclassified as internet nonusers in this study because some of them might answer "no" to the question "Did you use the internet or email in the past year?" Unfortunately, we could not identify which device was used for online communication. However, if online communication via mobile phones plays a protective role in developing depression, which is a plausible assumption, the association between online communication and developing clinical depression could be underestimated. Fourth, the types of online communication were not identified. Some might talk to friends/family online and others might send emails and/or messages to them. It remains unclear whether there is a specific type of online communication to prevent depression. Finally, we did not assess the frequency of internet use. The impact of online communication is presumably small among less frequent users. In addition, addictive use of the internet, particularly social media, has become an area of increasing research interest (Longstreeta & Brooks, 2017). Further studies are needed to figure out the appropriate frequency of online communication for preventing depression.

Conclusion

In a few decades, almost all older people, at least in developed countries, will be internet users because of a birth cohort effect, that is, the generation who grew up with the internet are aging. However, for current older people who have never used the internet as a young adult, there are several obstacles to use the internet, such as a lack of knowledge/support and negative perceptions of the internet. However, if we can convince older people to use the internet even once, the experience might increase self-efficacy (Adams et al., 2005). In one well-known case study of a rural agribusiness collective in a remote area of Japan, community developers demonstrated that older people (older than 70 years) could be successfully trained in the use of the internet (Hashimoto, 2012). This was accomplished by developing specialized hardware (e.g., large roller-ball mouses) and easy-to-use interfaces that could be navigated by older people. Today, many such devices and apps have been developed, making it easier for older people to use the internet. We should also focus on non-engineering aspects such as providing the information they want in an accessible way and activities they can enjoy easily to convince older people to adopt the internet. Online communication with friends/family could be an example of a persuasive portal to the internet. Our findings support the role of online communication with friends/family in preventing clinical depression among older people. Online communication could be particularly useful among older adults today as families are often geographically dispersed and, because of their vulnerability to the COVID-19, an alternative to face-to-face communication is required in the era of social distancing.

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Research Ethics

Ethical approval for the study was obtained from the Ethics Committee at Chiba University (approval number: 2493) and the National Center for Geriatrics and Gerontology (approval number: 992).

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Data Availability

Data are from the Japan Gerontological Evaluation Study (JAGES) study. All enquiries are to be addressed at the data management committee via e-mail: dataadmin.ml@jages.net. All JAGES data sets have ethical or legal restrictions for public deposition due to inclusion of sensitive information from the human participants.

Supplemental Material

Supplemental material for this article is available online.

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ORIGINAL ARTICLE

EPIDEMIOLOGY, CLINICAL PRACTICE AND HEALTH

Cross-national comparison of social isolation and mortality among older adults: A 10-year follow-up study in Japan and England

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Aim: Existing evidence links social isolation with poor health. To examine differences in the mortality risk by social isolation, and in socio-economic correlates of social isolation, we analyzed large-scale cohort studies in Japan and England.

Methods: Participants were drawn from the Japan Gerontological Evaluation Study (JAGES) and the English Longitudinal Study of Ageing (ELSA). We analyzed the 10-year mortality among 15 313 JAGES participants and 5124 ELSA respondents. Social isolation was measured by two scales, i.e., scoring the frequency of contact with close ties, and a composite measurement of social isolation risk. We calculated the population attributable fraction, and Cox regression models with multiple imputations were used to estimate hazard ratios (HRs) for mortality due to social isolation.

Results: The proportion of those with contact frequency of less than once a month was 8.5% in JAGES and 1.3% in ELSA. Males, older people, those with poor self-rated health, and unmarried people were significantly associated with social isolation in both countries. Both scales showed that social isolation among older adults had a remarkably higher risk for premature death (less frequent contact with others in JAGES: hazard ratio [HR] = 1.18, 95% confidence interval [CI]: 1.05–1.33, in ELSA: HR = 1.27, 95% CI: 0.85–1.89; and high isolation risk score in JAGES: HR = 1.30, 95% CI: 1.12–1.50, in ELSA: HR = 2.05, 95% CI: 1.52–2.73). The population attributable fraction showed less frequent contact with close ties was attributed to about 18 000 premature deaths annually in Japan, in contrast with about 1800 in England.

Conclusions: Negative health impacts of social isolation were higher among older Japanese compared with those in England. **Geriatr Gerontol Int 2021; 21: 209–214**.

Keywords: cross-national comparative study, mortality, population attributable risk, social isolation, social network.

Introduction

Along with becoming a super-aged society, Japan is experiencing a rapid increase in the number of never-married persons. Social isolation among older adults is an important issue in social work and public health in the context of social disconnection. Although several social gerontological theories have mentioned positive aspects of the aging process (e.g., disengagement theory,[1] socioemotional selectivity theory[2] and voluntary isolation[3]), social isolation among the aged is known to be linked with poor social support, loneliness, depressive symptoms, suicide, as well as physical inactivity and restricted mobility.[4,5] Berkman and Krishna reported that adequate social networks might influence health behaviors, psychological health, and physiological health through social support, social influence, norms around health, opportunities for social participation and social engagement, and access to material goods, resources and services.[6]

An overview of systematic reviews reported consistent evidence linking social isolation to all-cause mortality.[5] The influence of adequate social relationships on mortality risk is comparable with quitting smoking.[7] However, health impacts of social isolation might differ by nation, because the prevalence and aspects of social isolation differ by nation. For example, England is a more advanced country in this topic than Japan. In 2003, the Organisation for Economic Co-operation and Development (OECD) reported the proportion of respondents who rarely or never spent time with their close ties was different across countries, at 15.3% in Japan and 5.0% in the United Kingdom.[8] A recent report also showed social isolation among older adults is more severe in Japan than in England.[9] In England, some classic sociological studies[10,11] and systematic review of interventions targeting social isolation[12] have been performed. Disconnected communities are said to cost the United Kingdom economy as much as £32 billion per year.[13] Through those findings, the prime minister established a "minister of loneliness" in 2018 to tackle the social issues caused by social isolation and introducing social prescribing, in which general practitioners refer people experiencing loneliness to community activities.

There are different aspects of social isolation between Japan and England, but the differences in mortality risk and health impact of social isolation between Japan and England has been unknown. In addition, we cannot find any reports that directly measured social isolation by multiple scales with rich social demographic information. Therefore, the aim of this paper was to examine differences in the effects of social isolation on mortality and the socio-economic correlates of social isolation between Japan and England using large-scale prospective cohort data with the same statistical model. We also estimated the population attributable fraction of social isolation in Japan and England to interpret the role of social isolation closely in both countries.

Methods

Study design, participants and setting

We used longitudinal datasets collected from the Japan Gerontological Evaluation Study (JAGES) and the English Longitudinal Study of Ageing (ELSA). The JAGES delivered a self-administered questionnaire via a postal survey to older people who were aged ≥65 years and not eligible to receive long-term healthcare insurance benefits in Japan. In total, 15 313 respondents from the first wave in 2003 were randomly selected from six municipalities in Aichi Prefecture, located in central Japan. The study population in the ELSA who were aged ≥50 years and independently living in England were drawn from the Health Survey for England, which is described elsewhere.[14] We analyzed 5124 ELSA participants aged ≥65 years who participated from the first wave in 2002. According to census data, at the baseline survey, the proportion of older adults is higher in Japan (17.3% as of 2000) than England (15.9% as of 2001), and the population size of older adults is remarkably higher in Japan (about 22 million people) than England (about 8 million people).

The JAGES study protocol and informed consent procedure were approved by the Ethics Committee on the Research of Human Subjects at Nihon Fukushi University (10-05). Ethical approval for the ELSA was granted from the Multicentre Research and Ethics Committee (MREC/01/2/91).

Measures

Mortality

In the JAGES, information on mortality was obtained from official records of the public long-term care insurance system, which is run by municipal governments. The ELSA was linked to official records of hospital episode statistics and NHS central register (mortality) data.[14] Maximum survival time for both datasets was unified into 3436 days. The proportion of deceased people in the follow-up period was 25.4% in the JAGES and 40.1% in the ELSA.

Social isolation

Social isolation is referred to as having few contacts with family, friends or neighbors as primary social groups and has been treated as an objective condition.[10] We adopted two scales to capture social isolation: counting the frequency of social contact[4,10,11,15–17] and a multidimensional risk score.[4,18–20]

First, we used items asking the frequency of face-to-face and non-face-to-face contact with children, relatives or friends. These were measured by six categories from three or more times a week to less than once a year or never in the ELSA, and by seven categories from almost every day to none in the JAGES. We converted the items into number of monthly contacts, based on 4.3 weeks per month. The response items were then coded as none = 0, almost none = 0.1, once or twice a month = 1.5, once a week = 4.3, two or three times a week = 10.8 and up to almost every day = 21.5. All converted responses were added up and categorized into seven categories of less than once a month (≤1.0) to almost every day or more (≥38.7). We used the average score of contact with children and relatives in the ELSA for consistency with the JAGES questionnaire because they were all treated as family in the JAGES.

Second, considering previous indices[18–20] and comparable variables between the two surveys, we identified four dimensions of social isolation risk: unmarried, less regular contact with children living separately and relatives, less regular contact with friends and no social participation. Less regular contact was defined as less than two to three times a year based on summated face-to-face and non-face-to-face contact. Social participation included participation in any socially organized or religious groups, such as political organizations or groups, volunteer groups, senior citizen clubs, sports groups or clubs, neighborhood associations and hobby activity groups. We counted these applicable items, and classified them from 0 to ≥3 (0 = low risk of social isolation, ≥3 = high risk of social isolation).

Covariates

Covariates were sex and age of the participants, self-rated health, presence of medical treatment for existing health conditions, basic activities of daily living (ADL), marital status and household equivalized income at the baseline survey in both studies. Age was categorized as 65–74, 75–84 and ≥85 years. Self-rated health was categorized into four categories from poor to excellent; ELSA items on self-rated health were combined into the same category. Information to derive the presence of medical treatment was gathered from responses to items on the presence of heart conditions, chronic lung disease or glaucoma in the ELSA, and from responses to items on medical conditions in the JAGES. All responses were then summed up and dichotomized into yes = 1 or no = 0. Basic ADL were dichotomized by whether respondents were able to bathe, walk and toilet independently or not. Marital status was categorized as married, widowed or divorced, and single or never married. We derived household equivalized income by the square root of the numbers and grouped them into quintiles in each study. Distributions of those variables are shown in Table S1.

Table 1 Distributions of social relationships in each cohort survey

	JAGES (Japan)	ELSA† (England)
Frequency of contact with others		
More than almost every day	39.0	31.4
4–6 times a week	15.2	26.0
3–4 times a week	7.0	16.6
Twice a week to <3 times a week	11.0	11.5
Once a week to less than twice a week	9.5	9.1
Once a month to less than once a week	9.6	4.2
Less than once a month	8.7	1.3
Isolation risk score		
0	47.9	50.3
1	31.0	33.9
2	15.7	13.1
≥3	5.5	2.7

†ELSA data were after sampling weight. Unit: person.

Statistical analysis

After calculating the descriptive statistics, we conducted three analyses. Concerning ELSA, we used sampling weight to minimize bias from differential non-responses among key subgroups, as recommended.[14] First, we adopted Cox regression analysis to examine the association between social isolation and mortality, controlling for baseline covariates. We analyzed and compared the two scales of social isolation, separately. Second, to describe the correlates of socially isolated older adults, we adopted a Poisson regression for low frequency of contact with others and linear regression models for isolation risk score. In addition, 25.7% of JAGES and 26.2% of ELSA respondent had missing values in some variables. Therefore, we performed a multiple imputation technique by chained equations under the missing at random assumption, which means there might be systematic differences between the missing and observed values. In addition to the above control variables, we included geographical location, household size and ethnicity (only ELSA) as auxiliary variables to strengthen the missing at random assumption. We created 20 imputed datasets. Using each dataset, we estimated with the robust variance estimator. Finally, we calculated population attributable risk percentages (PAR%) in Japan and England. PAR%, which considers not only relative risk ratio but also proportion of exposure, is an important indicator to clarify health impact. This estimation assumed that the adjusted HRs truly reflected causal impact and that our results represent the entire older population. As the denominator, data on annual mortality were obtained from governmental reports in both countries.[21,22] We performed analyses using Stata 15.1 (Stata Corp LP, College Station, TX, USA).

Results

The proportion of socially isolated older adults was higher in Japan than England (Table 1). For instance, the proportion of adults in the category of social contact frequency of less than once a month was remarkably higher in Japan (JAGES = 8.7%, ELSA = 1.3%). Likewise, there were more people in Japan with isolation scores of ≥3 (JAGES = 5.5%, ELSA = 2.7%).

In both cohorts, mortality during the follow-up period was higher for socially isolated people (Table 2). After adjusting for individual attributes, Japanese older adults with contact frequency of less than once a month had a mortality risk of 1.18 (95% confidence interval [CI]: 1.05–1.33) times higher than that of those with contact almost every day or more. In ELSA, it was similar and respondents who had social contact less than once a month had the highest mortality risk of all (HR = 1.27, 95% CI: 0.85–1.89); however, it was not statistically significant, most likely due to the small power. The estimates of isolation score also showed similar results. In comparison with 0, participants with a score of ≥3 had a 1.30 (95% CI: 1.12–1.50) times higher risk for premature death in JAGES, and a 2.05 (95% CI: 1.52–2.73) times higher risk in ELSA. When we analyzed complete cases with raw data without multiple imputation, the major results and trends were not largely different (Table S2).

Poisson regression models showed the correlates of socially isolated older adults were almost similar in England and Japan, although some of ELSA data were not significant due to the small statistical power (Table 3). In comparison with women, men had a 2.3–3.0 times higher risk for low frequency of contact as severe social isolation (JAGES: prevalence ratio = 2.33, ELSA: prevalence ratio = 2.99). Older age, single and never married, dependence in basic ADL, and poor self-rated health had a higher risk for social isolation. Linear regression model results for multidimensional score also showed similar associations.

The estimation of PAR% showed about 19 000 premature deaths (1.6% of all deaths) could be avoided annually if there were fewer cases of severe social isolation in Japan (Table 4). In England, PAR% was remarkably different between the two scales. Less frequent contact with others and high isolation risk score could be associated with about 1800 (0.4% of all deaths) and 13 000 (2.7% of all deaths) premature deaths annually, respectively.

Discussion

Severe social isolation among older adults was associated with higher mortality risk in Japan and England, and the attributable fraction for the population cannot be ignored. To the best of our knowledge, this is the first study to examine the differences in the mortality risk and the possibility of health impacts of social isolation on premature death among older adults in Japan and England based on comparable large-scale prospective cohort surveys.

Table 2 Association between social isolation and mortality: Cox regression analysis[†]

		JAGES 2003 (10 years follow-up)				ELSA 2002 (10 years follow-up)			
		Deceased %	Adjusted HR[‡]	(95% CI)	*P*	Deceased %	Adjusted HR[‡]	(95% CI)	*P*
Frequency of contact with others	More than every day	23.4	Ref.			38.6	Ref.		
	4–6 times a week	24.8	1.02	(0.92–1.14)	0.641	34.7	0.93	(0.81–1.06)	0.276
	3–4 times a week	22.1	0.91	(0.79–1.06)	0.218	39.6	1.03	(0.86–1.23)	0.777
	2 to <3 times a week	25.3	0.99	(0.88–1.12)	0.893	37.1	0.96	(0.82–1.12)	0.595
	Once a week to <2 times a week	25.9	1.02	(0.90–1.15)	0.776	39.1	1.01	(0.82–1.24)	0.940
	Once a month to less than once a week	29.1	1.06	(0.94–1.19)	0.341	47.7	1.06	(0.85–1.33)	0.593
	Less than once a month	33.5	1.18	(1.05–1.33)	0.005	64.4	1.27	(0.85–1.89)	0.235
Isolation risk score	0	22.1	Ref.			31.1	Ref.		
	1	26.2	1.11	(1.02–1.21)	0.015	42.3	1.24	(1.11–1.39)	0.000
	2	30.2	1.18	(1.06–1.30)	0.002	48.0	1.45	(1.22–1.72)	0.000
	≥3	33.1	1.30	(1.12–1.50)	0.001	63.7	2.05	(1.52–2.73)	0.000

CI, confidential interval; HR, hazard ratio.

[†]Multiple imputation by chained equations was performed using frequency of contact with others (less than once a week), isolation score, sex, age, self-rated health, presence of medical treatment, marital status, equivalent income (quintile) and basic activities of daily living (m = 20). In addition, geographical location, household size and ethnicity (only ELSA) have included in these models as auxiliary variables to strengthen the missing at random assumption.

[‡]Sex, age, self-rated health, presence of medical treatment, marital status, equivalent income and basic activities of daily living at baseline were controlled.

Similar to a previous report,[8] our results suggested that the prevalence of social isolation, that is, less frequent contact with others and high isolation risk score, among older adults in Japan was more than twice that in England. We confirmed the correlates of the isolated people did not largely differ between the two countries. This is also consistent with previous studies that mentioned several risk factors for social isolation in the older population: being male, advanced age, poor health and

Table 3 Correlates of social isolation among older adults: Poisson regression and multiple-linear regression analysis [†]

		Low frequency of contact with others: less than once a month						Isolation risk score (0 to ≥3)			
		JAGES 2003			ELSA 2002			JAGES 2003		ELSA 2002	
		PR	(95% CI)	P	PR	(95% CI)	P	β	P	β	P
Sex	Female	Ref.			Ref.			Ref.		Ref.	
	Male	2.33	(2.05–2.66)	0.000	2.99	(1.63–5.48)	0.000	0.121	0.000	0.066	0.000
Age, years	65–74	Ref.			Ref.			Ref.		Ref.	
	75–84	1.15	(1.02–1.30)	0.022	1.84	(1.05–3.23)	0.032	0.032	0.002	0.037	0.019
	≥85	1.71	(1.36–2.15)	0.000	2.47	(0.97–6.27)	0.057	0.068	0.000	0.054	0.003
Self-rated health	Poor, very poor	Ref.			Ref.			Ref.		Ref.	
	Fair	0.97	(0.77–1.22)	0.807	0.67	(0.28–1.56)	0.351	−0.051	0.008	−0.037	0.146
	Good	0.66	(0.53–0.83)	0.000	0.58	(0.25–1.32)	0.194	−0.138	0.000	−0.048	0.086
	Excellent, very good	0.48	(0.34–0.67)	0.000	0.78	(0.33–1.83)	0.566	−0.106	0.000	−0.025	0.293
Presence of medical treatment	No	Ref.			Ref.			Ref.		Ref.	
	Yes	0.88	(0.77–1.01)	0.076	0.81	(0.41–1.60)	0.543	−0.005	0.595	0.006	0.675
Marital status	Married	Ref.			Ref.			Ref.		Ref.	
	Widowed, divorced	1.17	(1.00–1.36)	0.048	0.73	(0.37–1.43)	0.359	0.034	0.002	0.061	0.000
	Single, never married	2.17	(1.54–3.07)	0.000	2.79	(1.24–6.26)	0.013	0.145	0.000	0.445	0.000
Equivalent income (quintile)	Lowest	1.20	(0.99–1.45)	0.071	1.37	(0.64–2.93)	0.419	0.039	0.003	0.004	0.825
	Low	1.08	(0.87–1.33)	0.487	0.91	(0.36–2.31)	0.846	0.010	0.472	0.012	0.532
	Middle	Ref.			Ref.			Ref.		Ref.	
	High	1.12	(0.91–1.38)	0.289	1.02	(0.46–2.26)	0.968	−0.012	0.341	−0.045	0.015
	Highest	0.97	(0.79–1.19)	0.746	0.67	(0.26–1.74)	0.412	−0.013	0.322	−0.105	0.000
Basic ADL	Independent	Ref.			Ref.			Ref.		Ref.	
	Dependent	1.38	(1.05–1.83)	0.022	1.35	(0.71–2.55)	0.361	0.036	0.001	0.062	0.000

β, standard partial regression coefficient; ADL, activities of daily living; CI, confidential interval; PR, prevalence ratio.

[†]Multiple imputation by chained equations was performed using frequency of contact with others (less than once a week), isolation score, sex, age, self-rated health, presence of medical treatment, marital status, equivalent income (quintile) and basic ADL (m = 20). Additionally, geographical location, household size, and ethnicity (only ELSA) have included in these models as auxiliary variables to strengthen the missing at random assumption.

Table 4 Population attributable risk fraction of social isolation

				PAR	
		Expose % (95% CI) †	HR	%‡ (95% CI)	*n*§
Japan	Low frequency of contact (less than once a month)	8.7 (8.2–9.2)	1.18	1.6 (1.5–1.6)	18 799 (17 788–19 809)
	Isolation risk score (≥3)	5.5 (5.1–5.9)	1.30	1.6 (1.5–1.7)	19 522 (18 179 –20 863)
England	Low frequency of contact (less than once a month)	1.4 (1.1–1.7)	1.27	0.4 (0.3–0.5)	1827 (1422–2232)
	Isolation risk score (≥3)	2.7 (2.3–3.1)	2.04	2.7 (2.3–3.2)	13 209 (11 154–15 247)

HR, hazard ratio; PAR, population attributable risk.

†% exposed is in our analyzed dataset.

‡PAR% $= \frac{Pe(HR-1)}{Pe(HR-1)+1}$ *Pe*, the proportion of exposure in the target population.

§Denominator is the annual number of mortalities among people ≥65 years, which was obtained from governmental reports.[21,22]

England: N = 422 159 (2017); Japan: N = 1 208 908 (2017).

[Correction added on 21 January 2020, after first online publication: The data for *n*§ in Table 4 has been corrected from "18 799 (15 836–17 638)" to "18 799 (17 788–19 809)".]

low socio-economic status.[4,10,11] It is important to note that we confirmed these prevalences and correlates using the present data, while previous research mentioned the key studies had been conducted well over 30 years ago.[4] These results suggest that the correlates of socially isolated older adults are almost unchanged over the long term, although the prevalence differs by nation.

There are several possible reasons why the point estimation (HRs) of social isolation for mortality was higher in England, although we did not estimate the significance of the difference between Japan and England. The concept of feelings of relative deprivation[23] might capture very severe conditions in a comparatively connected society. It was reported that social isolation might strongly enhance social stress for older Japanese women, as such isolation is rare in the community.[15] Another analysis reported that better friendship-based social relationships lengthened survival among men in England by 45.4 days compared with men in Japan.[24] In a connected society, most people receive the benefits of better social relationships. However, social isolation among people in a connected society might be more severe than that in a disconnected society.

According to our estimation of the population attributable risk percentages calculated using the proportion of exposure ratio and HR, about 1.6% of annual deaths in Japan are associated with social isolation. This is of concern because the aging population is huge in Japan. Social isolation among older adults is a risk factor that can be modified with diverse interventions.[25] Recently, evaluations and intervention studies on the promotion of social participation and social relationships are progressing in Japan.[26] Nationwide promotion of social participation and relationships is also necessary in Japan to combat social isolation among older adults.

Our study added new evidence about the cut-off point of severe social isolation. Tunstall mentioned that where the cut-off point is placed along the continuum of social contact is inevitably arbitrary.[11] Our results suggested that contact with others less than once a month becomes one criterion of severe social isolation in Japanese older adults, which is associated with risk of premature death. Although it was not statistically significant due to the small power, the result of ELSA showed a similar trend. Contact frequency of less than once a month might reflect qualitatively different conditions, including poor social support[27] and eating alone,[28] which contribute to health risks. In addition, the composite measurement score showed a stronger association and dose–response trend with mortality, although the cut-off point was unclear. As overlapping multidimensional disadvantage is more strongly associated with premature death,[29] it might capture not only social isolation in a narrow sense, but low socio-economic status and social vulnerability.

Our study has several limitations. First, we assessed social isolation and covariates only at baseline. Therefore, we cannot deny the possibility of reverse causation, although we adopted several statistical techniques. On the other hand, our findings may be underestimated because people living in serious social isolation may have been less likely to participate in these surveys. Second, we cannot discuss the mechanisms between social isolation and mortality. Control variables in our models were also limited because we considered comparability between the two surveys. For instance, although several studies suggested transport difficulties including driving cessation, or geographic location as possible risk factors for social isolation among older adults, we could not include these factors.[30] Third, JAGES data are not representative of the whole country. However, it is important to note that we did perform a large-scale survey concerning social isolation among older adults in more than one municipality in Japan. Fourth, our baseline survey data are dated because we focused on the association with mortality. We could not reflect diversification of social contact means across decades. Fifth, there might be cultural differences in the meanings of "friend" and "close relationship" between countries. However, we believe the bias would not explain all of the differences in our results. It would be meaningful to examine the association between social isolation and mortality in another cross-national comparison with the same framework in the future.

In conclusion, the results showed social isolation among older adults was associated with mortality in both Japan and England, and the socio-economic correlates of social isolation were similar. One important implication of our findings is that the health impacts of social isolation might differ by nation. Negative health impacts of social isolation were higher and should not be ignored among older Japanese.

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Supporting Information

Additional supporting information may be found in the online version of this article at the publisher's website:

Table S1 Distributions of covariates in each cohort survey
Table S2. Association between social isolation and mortality in the raw data: complete case analysis

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Mediation of the relationship between home loss and worsened cardiometabolic profiles of older disaster survivors by post-disaster relocation: A natural experiment from the Great East Japan earthquake and tsunami

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Highlights

·We investigated the mechanisms for worsening health among disaster survivors.

·Post-disaster relocation explains increased body mass index and waist circumference.

·Worsening triglycerides and HDL/LDL cholesterol are not explained by relocation.

·Disaster damage appears to affect different health outcomes via specific pathways.

Abstract

The underlying mechanism for deterioration in cardiometabolic health after major natural disasters is unknown. We leveraged natural experiment data stemming from the 2011 Great East Japan Earthquake and Tsunami (n = 1165) to examine whether specific types of post-disaster

accommodations explain the association between disaster-related property damage and objectively measured cardiometabolic profiles of older disaster survivors. Causal mediation analysis showed that relocation to trailer-style temporary shelters largely mediated the associations between home loss and unhealthy changes in anthropometric measures (72.6% of 0.65 kg/m^2 for body mass index and 62.3% of 3.89 cm for waist circumference), but it did not mediate the associations with serum lipid measures. This study demonstrates that there are outcome-specific pathways linking disaster damage and health of survivors.

Keywords

Disaster; Cardiometabolic; Neighborhood; Mediation; Natural experiment; Fixed effects

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Intensity of community-based programs by long-term care insurers and the likelihood of frailty: Multilevel analysis of older Japanese adults

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ABSTRACT

The World Health Organization (WHO) argues that governments can postpone declining capacity of older adults by providing sufficient support. Yet, to our knowledge, no study has focused on the role of local governments for realizing healthy ageing. This study examined the association between the intensity of community-based programs for frailty postponement by long-term care insurers (as municipalities) and the likelihood of frailty. We analyzed repeated cross-sectional data of three waves (2010-11, 2013, and 2016) from the Japan Gerontological Evaluation Study (JAGES). Participants included 375,400 older adults aged 65 years or older (M = 74.1) living in a total of 81 regions covered by insurers in Japan. Frailty was assessed by a governmental standardized index, the Kihon Check List (KCL; a basic function check list in Japanese). Estimations were obtained using a multilevel logistic model with random slopes. We found that every social activity per hundred older people organized by a long-term care insurer was significantly associated with an 11% reduction of the likelihood of frailty (Odds ratio = 0.89; 95% credible interval = 0.81, 0.99). Although the main effect of educational events was not significant, the point estimate was slightly larger for people with lower levels of education than for those with higher education. The results also suggested that insurer-organized social activities could be more beneficial in communities with few opportunities for civic participation. The variation in intensity of community-based programs by long-term care insurers may explain part of a disparity in the likelihood of frailty between municipalities.

1. Introduction

The World Health Organization (WHO) defines "healthy aging" as "the process of developing and maintaining the functional ability that enables wellbeing in older age" (World Health Organization, 2015). Interventions targeting frailty and deterring disability are essential to promote healthy aging. Frailty is an age-related physiological syndrome that puts older people at a greater risk for adverse health outcomes such as falls, institutionalization, hospitalization, and death (Fried et al., 2001; Kan et al., 2008). It should be noted that there are still some debates on the definition of frailty (Clegg et al., 2013; Collard et al., 2012). While Rockwood and colleagues defined frailty as cumulative deficits including disabilities, diseases, symptoms, signs, and laboratory abnormalities (Jones et al., 2004; Mitnitski et al., 2001; Peña et al., 2014; Rockwood and Mitnitski, 2007; Rockwood et al., 2005), Fried and colleagues defined it as a physical phenotype and argued that researchers should distinguish frailty from disability and comorbidity (Fried et al., 2004; Fried et al., 2001). Although the two definitions are somewhat overlapped (Cigolle et al., 2009; Rockwood et al., 2007), the latter seems more practical because each condition (namely, frailty, disability, and comorbidity) needs different medical and long-term care services (Fried et al., 2004). Moreover, the latter view fits better into

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the context of aiming at healthy aging and attracts policy makers' attention to frailty as a good target for interventions, given that frailty is a reversible condition and a precursor of disability (Fried et al., 2004; Kan et al., 2008; Lang et al., 2009; Vermeulen et al., 2011). The WHO also argues that governments can reverse or slow declining capacity of older people by providing sufficient support (World Health Organization, 2015). Despite the important role of governments, to our knowledge, no study has focused on the responsibility of local governments for postponement of frailty.

Many interventions for frailty such as exercise (Clegg et al., 2012; de Vries et al., 2012; Theou et al., 2011), nutritional support (Halfon et al., 2015; Kim and Lee, 2013; Maggio et al., 2013), cognitive training (Ng et al., 2015), comprehensive geriatric assessment (Ellis et al., 2017), and their combinations (Kim et al., 2012; Luger et al., 2016; Ng et al., 2015) have been proposed and substantiated. Most of these interventions target those who are already frail or pre-frail. These approaches, however, can help only a limited number of people. One study estimated that the prevalence of frailty is 11.3% in Japan (Shimada et al., 2013), which corresponds to over 5 million people. As frailty is such a common condition among older people, community-based strategies for decreasing frailty in the general population should be developed (Sacha et al., 2017). As the most rapidly aging society in the world, insurers of long-term care insurance (LTCI) in Japan (where an insurer is a single municipality in general, though some small municipalities administer the LTCI jointly) have developed various community-based programs that seem beneficial for decreasing frailty.

One of the potential strategies for postponement of frailty is the encouragement of social participation. The town of Taketoyo, Japan, has created community centers called "salons," in which older residents gather and engage in various social activities (e.g., light exercise, singing, playing games, drinking tea). Researchers have revealed that participants in the salon programs have better self-rated health and lower likelihood of functional and cognitive disability than non-participants, addressing endogeneity through the use of an instrumental variable (the distance between a house and the nearest salon) (Hikichi et al., 2017, 2015; Ichida et al., 2013). Motivated by the example of Taketoyo, many insurers now provide older citizens with public spaces such as community centers, libraries, or classrooms in local schools to help them hold social activities. Another means of social participation—volunteering—may also help older people maintain their robustness. Previous studies have shown that volunteering is associated with better psychosocial, physical, and cognitive outcomes in older people (Anderson et al., 2014; Jung et al., 2010). LTCI insurers train residents and send them as volunteers to nursing homes, households of elderly people living alone, and neighborhood watch programs. Some insurers incentivize older residents to participate in volunteering by rewarding them with "volunteer points," which participants can use to shop at local shopping malls and exchange as payment for LTCI. Encouragement of social participation thus seems promising, but there is a drawback to consider. Sex, health status, socioeconomic status (SES), and social connection are known determinants of participation in social activities and volunteering (Hikichi et al., 2017; Niebuur et al., 2018). Consequently, if people who have poor health, low SES, and are isolated are less likely to participate in such activities, interventions focusing on social participation may widen the disparity in healthy aging.

Another approach to decreasing frailty is providing education and training (World Health Organization, 2017). Many insurers arrange educational events for postponement of frailty, in which older people learn how to maintain their robustness through healthy behaviors such as physical activity, following a nutritious diet, oral care, and cognitive exercise. Yet, the effect of such educational programs on the general population is still unclear (Albrecht et al., 2016; Ebrahim et al., 2011; Schoberer et al., 2016).

Insurers can use funding from LTCI for initiating measures to encourage social participation and organize educational events. Nevertheless, the intensity of these measures differs across the nation; some insurers arrange social activities for older residents 10,000 to 40,000 times in a year, while others organize such activities only once or never. Thus, we hypothesize that the variation in intensity of interventions by insurers can explain part of the regional disparity that exists in the likelihood of frailty. In other words, our research question is whether older people under insurers dedicated to measures for postponement of frailty are less likely to be frail than those under less-dedicated insurers.

This study used a large amount of data from a nationwide study on older Japanese adults to examine associations between the number of times that an insurer organized educational events and social activities on the one hand, and the likelihood of frailty among community-dwelling older adults on the other. Moreover, by including variables of SES (as educational attainment) and social capital (defined as "resources that are accessed by individuals as a result of their membership of a network or a group"; Kawachi and Berkman, 2014), we evaluated whether the community-based strategies could shrink the disparity among people of different SES and between communities in the likelihood of frailty. Although we did not directly assess individual participation in the programs and thus could not infer causality, this study is the first to explore the association between intensity of community-based intervention efforts by insurers and decrease in frailty, given the important role of local governments in achieving healthy aging, as highlighted by the WHO.

2. Method

2.1. Study participants

We used repeated cross-sectional data from the Japan Gerontological Evaluation Study (JAGES). The JAGES is a large observational study, including natural experiment (Hikichi et al., 2016) and community intervention (Hikichi et al., 2017, 2015; Ichida et al., 2013), of Japanese people aged 65 or older who are physically and cognitively independent (that is, not certified as needing long-term care). Our data came from three waves of the study conducted in 2010–2011, 2013, and 2016. In each wave, 22, 25, and 34 insurers of the LTCI participated, respectively. Self-reported questionnaires were mailed to eligible residents; random sampling methods were used by 42 large insurers, while a census of all eligible residents was conducted in 39 smaller insurers. In the large insurers, participants who answered a questionnaire in a previous wave were oversampled in the following wave. In the three waves, questionnaires were collected from 112,123, 137,736, and 196,438 participants, respectively, corresponding to response rates of 66.3%, 71.1%, and 70.2%, respectively. Participants who reported depending on others for activities of daily living (ADL) (n = 37,207) were excluded from the analysis because we considered frailty as the previous stage of disability (Fried et al., 2004; Kan et al., 2008; Vermeulen et al., 2011). Participants whose sex and age could not be confirmed or were reported in error (n = 33,690) were also excluded. This study was reviewed and approved by ethics committees at the University of Tokyo, Nihon Fukushi University, National Centre for Geriatrics and Gerontology, and Chiba University. We acquired permission to use the data from the JAGES investigators.

2.2. Frailty measure

Frailty was assessed by a governmental standardized index named the Kihon Check List (KCL, a basic function checklist in Japanese). The KCL was originally developed by Japan's Ministry of Health, Labour, and Welfare (MHLW) to identify those who are at high risk of disability. The JAGES incorporates the KCL into its questionnaire. The KCL consists of 25 questions in the domains of physical, oral, social, and cognitive functions, nutritional status, and depressive mood (see Appendix Table A1). The most widely used definition of frailty is the Fried criteria (Fried et al., 2001) that features five phenotypes (shrinking, exhaustion,

low levels of activity, weakness, and slowness). Under these criteria, frailty, pre-frailty, and robustness are defined as when an individual meets ≥3, 1–2, and 0 of the five phenotypes, respectively. In a clinical setting, Satake et al. (2016) verified that an individual's total KCL score is closely correlated with the number of Fried's phenotypes that describe him or her (ρ = 0.655; c-statistic was 0.81 for pre-frailty and 0.92 for frailty) and proposed to define states with a KCL value of 4 and over as pre-frailty (sensitivity 70.3%; specificity 78.3%) and of 8 and over as frailty (sensitivity 89.5%; specificity 80.7%). We adopted these cut-off values and constructed binary variables indicating the status of pre-frailty (assigning the value of 1 to those who scored 4 and over, thus also including those who were frail in this category) and of frailty (those who scored 8 and over). Then, we conducted logistic regressions on the two outcomes with separated samples.

2.3. Predictors and other covariates

Our primary predictor was the annual number of times that an insurer took measures for postponement of frailty per hundred older adults. The MHLW categorizes the measures into (1) educational events and (2) promotion of social activity. Educational events include consultation events and seminars for postponement of frailty. For the promotion of social activity, insurers train older volunteers and arrange their activities. They also provide public spaces where older citizens can congregate and encourage them to participate in social activities. The number of times that an insurer organized educational events and social activities was extracted from the Report on Preventive Long-Term Care Service, into which reports from insurers are compiled by the MHLW, corresponding to the years of the JAGES investigations. It was divided by the population aged 65 or older insured by each insurer, using data from the Basic Resident Register administrated by Japan's Ministry of Internal Affairs and Communications.

Secondary predictors were educational attainment and social capital. For educational attainment, we categorized participants into three groups: low (9 years or less), middle (10–12 years), and high (13 years or more) levels of education. To measure social capital, we used three scales consisting of civic participation, social cohesion, and reciprocity validated by Saito et al. (2016). The previous study validated community-level social capital, which is equal to the average score of each of these three scales within a school district (it often represents the unit of a former village, and community activities such as senior citizens clubs, agricultural cooperatives, and local festivals take place within each district). Civic participation was measured as the number of the following groups engaged in per month: volunteer groups, sports groups, and hobby groups. Social cohesion was measured as the number of participants who answered “strongly/moderately agree” on three questions about community trust, norms of reciprocity, and community attachment. Reciprocity was measured as the number of participants who answered “any one or more” on three questions about receiving and providing emotional support and receiving instrumental support. Each variable ranged from 0 to 3, and we included both individual- and community-level scores at level 1 in our three-level models described later because previous studies showed that individual social capital cannot fully explain disparities in the onset of functional decline, and community social capital affects it contextually (Aida et al., 2013; Fujihara et al., 2019). To examine whether the community-based interventions could shrink disparities in frailty, we included interaction terms—that is, the number of interventions, along with educational attainment and scores of social capital in our model.

We also adjusted for sex, age, annual equivalized household income (low (≤1.9), middle (2.0–3.9), and high (≥4.0) million Japanese Yen (JPY, 1US$ = approximately 108JPY in November 2019), marital status (married, widowed, divorced, and never married), employment status (employed or not), and fixed effects of the year of investigation (2013 or 2016).

2.4. Statistical analysis

Considering the heterogeneity of regions covered by insurers, we used multilevel logistic models to evaluate associations between the number of interventions and the likelihood of frailty and pre-frailty. The data was a repeated cross-sectional design and structured in three levels; individuals at level 1 were nested within the years of investigation at level 2, nested within insurers at level 3. The number of interventions and fixed effects of the years of investigation are variables at level 2; all of the other covariates were measured at level 1. We included random slopes of the year of investigation at level 3 to allow time-variant effects of interventions to be heterogeneous across insurers. Estimates were obtained using Markov Chain Monte Carlo (MCMC) methods (Browne, 2017). To mitigate potential biases caused by these missing values, we adopted multiple imputations under the missing at random (MAR) assumption. Incomplete variables were imputed by a multivariate normal model using all the covariates as explanatory variables: sex, age, years of education, equivalized household income, marital status, employment status, the 25 items of the KCL, year of the investigation, municipality of residence, and the three items of civic participation, social cohesion, and reciprocity. We created 10 imputed datasets, and the estimates were combined. Multilevel analyses were performed with MLwiN, version 3.02 (Centre for Multilevel Modelling, University of Bristol) via Stata, version 14.2 (Stata Corp, College Station, TX) (Charlton et al., 2017; Leckie and Charlton, 2013). All other analyses were conducted using Stata.

3. Results

3.1. Participant characteristics

As shown in Table 1, there was a declining trend for the prevalence of pre-frailty and frailty (pre-frailty: 2010–2011: 59.9%; 2013: 47.3%; 2016: 38.5%, frailty: 2010–2011: 25.1%; 2013: 16.1%; 2016: 9.9%). It may reflect a trend that Japanese people aged 65 and over now score 5–10 years younger in physical and psychological health than they used to 10–20 years ago (Ouchi et al., 2017). In the descending waves, the social capital scores of civic participation and reciprocity had improved at both the individual and community level.

Between insurers, there were variations of the prevalence of pre-frailty and frailty. The prevalence of pre-frailty ranged from 52.2% to 73.2% in 2010–2011, from 39.0% to 61.1% in 2013, and from 29.0% to 44.9% in 2016. For the same years, the prevalence of frailty ranged from 18.6% to 37.2%, from 12.2% to 24.4%, and from 7.1% to 14.3%, respectively. On average, insurers arranged educational events from 2.09 to 3.63 times per hundred older adults per year and social activities from 1.74 to 3.49 times. The number of interventions also varied by insurer; some insurers arranged interventions more than 10 times the average, whereas others arranged none.

3.2. Multilevel analysis

Table 2 shows the results of our multilevel logistic analyses. Social capital may act as a mediator because interventions can promote social capital. Thus, we ran regressions excluding social capital related variables in Model 1 and then added them in Model 2. We found that each social activity per hundred older people was significantly associated with an 11% reduction of the likelihood of frailty (*OR* = 0.89; 95% credible interval [*CI*] = 0.81, 0.99) in Model 2. Comparing to Model 1, the estimated associations of interventions with outcomes got stronger rather than weaker after adjusting for social capital. Hence, social capital appeared to act as a confounder, rather than a mediator.

We also checked whether educational attainment and social capital act as effect modifiers. Although the main effect of educational events on the likelihood of frailty was negative but non-significant, an interaction term with a dummy variable indicating a low level of education

Table 1
Participant characteristics.

	2010–2011	2013	2016	*p*-value
Individual				
N	97,745	119,947	157,708	
Pre-frailty (%)	59.9	47.3	38.5	< 0.001
Frailty (%)	25.1	16.1	9.9	< 0.001
Male (%)	46.3	46.6	46.3	0.10
Age (*M* (*SD*))	74.0 (6.14)	73.7 (6.10)	73.8 (6.05)	< 0.001
Education (%)				< 0.001
Low (≤9 years)	47.6	41.0	31.6	
Middle (10–12 years)	34.7	38.1	41.8	
High (≥13 years)	17.8	20.9	26.6	
Equivalized household income (%)				< 0.001
Low (≤1.9 million JPY)	50.7	50.8	48.4	
Middle (2.0–3.9 million JPY)	38.4	38.4	40.2	
High (≥4.0 million JPY)	10.9	10.8	11.5	
Marital status (%)				< 0.001
Married	72.3	73.4	73.6	
Widowed	22.4	20.9	19.0	
Divorced	3.3	3.5	4.5	
Never married	2.1	2.3	3.0	
Employed (%)	23.2	24.6	29.6	< 0.001
Individual social capital (*M* (*SD*))				
Civic participation score	0.65 (0.87)	0.66 (0.89)	0.79 (0.99)	< 0.001
Social cohesion score	2.12 (1.06)	2.03 (1.09)	2.03 (1.09)	< 0.001
Reciprocity score	2.82 (0.55)	2.83 (0.53)	2.85 (0.50)	< 0.001
Community social capital (*M* (*SD*))				
Civic participation score	0.70 (0.15)	0.71 (0.15)	0.83 (0.16)	< 0.001
Social cohesion score	2.10 (0.18)	2.01 (0.17)	2.01 (0.16)	< 0.001
Reciprocity score	2.81 (0.06)	2.82 (0.06)	2.83 (0.06)	< 0.001
Insurer				
N	22	25	34	
Pre-frailty (%) (Min-Max)	52.2–73.2	39.0–61.1	29.0–44.9	
Frailty (%) (Min-Max)	18.6–37.2	12.2–24.4	7.1–14.3	
Educational events per hundred older adults				
M (*SD*)	2.96 (3.46)	3.63 (7.24)	2.09 (4.73)	0.55
Min-Max	0.0–15.3	0.0–36.7	0.03–27.4	
Social activities per hundred older adults				
M (*SD*)	1.74 (4.43)	3.43 (8.59)	3.49 (8.28)	0.66
Min-Max	0.0–21.1	0.0–36.3	0.0–43.3	

Note. p-values for χ^2 test and one-way ANOVA across the waves are displayed. M = Mean; SD = standard deviation; JPY = Japanese Yen (1US$ = approximately 108JPY in November 2019).

showed a negative significance. The difference in point estimates was very slight (for those with a high level of education: *OR* = 0.92; 95% *CI* = 0.78, 1.08, while for those with a low level of education: *OR* = 0.91; 95% *CI* = 0.77, 1.08 in Model 2), but the significance of the interaction term suggests that educational interventions might fill a gap in knowledge and the likelihood of frailty. By contrast, an interaction term between social activity and a low level of education showed a positive significance, though the point estimate for those with a low level of education was still negative and narrowly missed conventional significance (*OR* = 0.90; 95% *CI* = 0.81, 1.004). Interaction terms with community-level social capital, educational event–social cohesion and social activity–civic participation were significantly positive, which suggests that the interventions' effects on decreasing frailty were larger for those who lived in a community where such social capital was inadequate. Yet, the interaction term between educational event and community civic participation was statistically significant, which suggests that education-based interventions might be more effective in communities where civic participation is more active. In contrast to frailty, few variables were associated with the likelihood of pre-frailty (see Fig. 1).

4. Discussion

To our knowledge, this study is the first to explore the association between intensity of community-based intervention efforts by LTCI insurers and decrease in frailty. Using multilevel analysis, we found a reduced likelihood of frailty among older adults covered by insurers that organized more social activities. A previous randomized control trial revealed that social support alone was comparable to physical training and nutritional intervention and successfully decreased frailty (Luger et al., 2016). Taken together, our finding supports that providing opportunities for social interactions through community-based programs helps older adults maintain their capacity.

Although the main effect of educational events on frailty was not significant, it negatively interacted with an indicator of a lower level of education. This finding suggests that educational programs were more beneficial for people with lower levels of education, and thus might fill knowledge gaps between different socio-economic groups. By contrast, social activity positively interacted with the indicator of a low level of education (i.e., it was more effective among people with higher levels of education). Given that people with lower levels of education are less likely to participate in volunteering (Niebuur et al., 2018), those with lower education would be less benefited by interventions even if insurers provide opportunities for volunteering because they are less likely to participate in them. Another study, however, pointed out that they were more likely to participate in gathering at community centers than those with higher education (Hikichi et al., 2017). Further studies are thus needed to confirm relationships between educational attainment, participation in social activities, and the effect of community-based interventions.

Another important finding was the differential effects of the interventions by community-level social capital. Our findings suggest that social activities organized by insurers were more meaningful in communities with few opportunities for civic participation. From individualistic views, it has been known that participation in social activities (Hikichi et al., 2017, 2015; Ichida et al., 2013) and volunteering (Anderson et al., 2014; Jung et al., 2010) is salutary for older people. Yet, older people face difficulties in finding such opportunities in a community with insufficient social capital, which widens regional disparities in geriatric health. In health research, considering variation in community-level social capital is important because it can explain health outcomes even after adjusting for individual-level covariates (Koyama et al., 2016; Mohan et al., 2005; Sundquist et al., 2006). For example, a previous study found that lower levels of community social capital was associated with an elevated risk of functional disability among older women after adjusting for individual risk factors (Aida et al., 2013). Adding to the previous findings, the present study suggests that the creation of salons and the promotion of volunteering by insurers may facilitate social activities and mitigate disadvantages in communities with low stocks of social capital (e.g., few opportunities for civic participation). The WHO asserts that the environment older people inhabit is key to healthy aging as it can make up for their declining intrinsic capacity (both physical and mental) and maintain functional ability (World Health Organization, 2015). The present study makes a contribution to the promotion of healthy aging by suggesting that local governments can create environments where older people can continue participating in social activities and realize their potential.

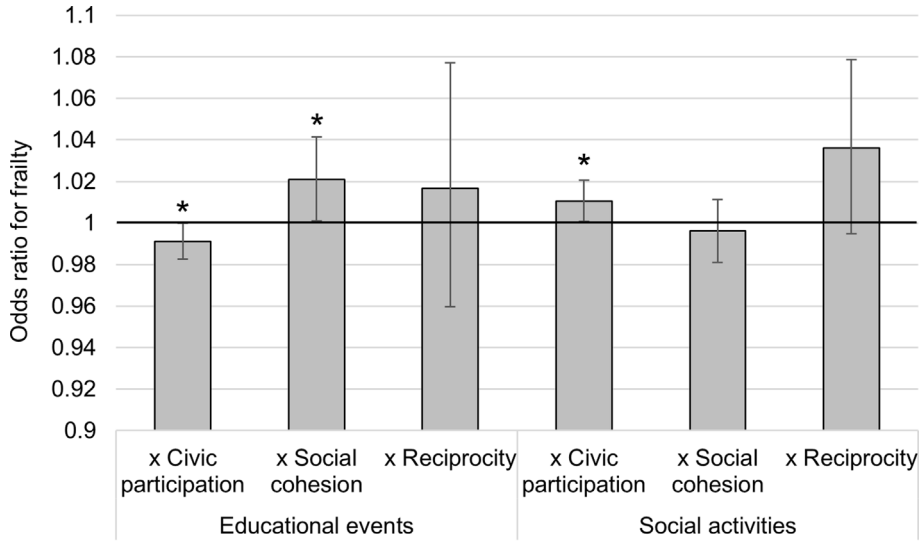
4.1. Limitations

The present study had several limitations. First, we measured an ecological effect of community-based interventions and could not determine from the JAGES data whether the participants actually took part in the educational events and social activities organized by insurers. Therefore, we are unable to conclusively infer if the lower risk of frailty was attributable to the programs. Our study was exploratory, which assumed that the more opportunities for community-based programs long-term care insurers provided, the more community-dwelling older adults would participate in them. Yet, if unobserved factors confounded the associations, our findings can be biased. Thus, it should

Table 2
The association between the number of times of interventions and the likelihood of pre-frailty and frailty.

Variables	Pre-frailty						Frailty					
	Model 1			Model 2			Model 1			Model 2		
	OR	95% *CI*		*OR*	95% *CI*		*OR*	95% *CI*		*OR*	95% *CI*	
Educational attainment												
Low education	1.57***	1.53	1.60	1.40***	1.36	1.43	1.69***	1.64	1.75	1.48***	1.43	1.53
Middle education	1.15***	1.13	1.18	1.11***	1.09	1.14	1.22***	1.18	1.26	1.17***	1.13	1.21
High education	ref.			ref.			ref.			ref.		
Individual SC												
Civic participation				0.74***	0.73	0.75				0.66***	0.65	0.67
Social cohesion				0.77***	0.76	0.77				0.73***	0.72	0.74
Reciprocity				0.61***	0.59	0.62				0.64***	0.62	0.65
Community SC												
Civic participation				0.93**	0.89	0.98				0.93*	0.87	0.99
Social cohesion				1.10*	1.02	1.18				1.06	0.97	1.16
Reciprocity				0.78*	0.65	0.94				0.85	0.66	1.09
Educational events	1.00	0.98	1.02	0.93	0.82	1.05	1.01	0.97	1.05	0.92	0.78	1.08
Interactions with education												
× Low education	1.00	1.00	1.01	1.00	1.00	1.01	0.99*	0.98	0.998	0.99*	0.98	0.999
× Middle education	1.00	1.00	1.01	1.00	1.00	1.01	0.99	0.98	1.00	0.99	0.98	1.00
× High education	ref.			ref.			ref.			ref.		
Interactions with individual SC												
× Civic participation				1.00	1.00	1.00				1.00	0.99	1.00
× Social cohesion				1.00	1.00	1.00				1.00	1.00	1.00
× Reciprocity				1.00	1.00	1.01				1.00	1.00	1.00
Interactions with community SC												
× Civic participation				1.00	0.99	1.01				0.99*	0.98	0.9999
× Social cohesion				1.01	1.00	1.03				1.02*	1.001	1.04
× Reciprocity				1.01	0.97	1.05				1.02	0.96	1.08
Social activities	0.98	0.96	1.00	0.96	0.89	1.03	0.98	0.93	1.03	0.89*	0.81	0.99
Interactions with education												
× Low education	1.00	1.00	1.00	1.00	1.00	1.00	1.01***	1.003	1.01	1.01**	1.002	1.01
× Middle education	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.00	1.00	1.01
× High education	ref.			ref.			ref.			ref.		
Interactions with individual SC												
× Civic participation				1.00	1.00	1.00				1.00	1.00	1.00
× Social cohesion				1.00	1.00	1.00				1.00	1.00	1.00
× Reciprocity				1.00	1.00	1.00				1.00	1.00	1.00
Interactions with community SC												
× Civic participation				1.00	1.00	1.01				1.01*	1.001	1.02
× Social cohesion				0.99	0.98	1.00				1.00	0.98	1.01
× Reciprocity				1.02	0.99	1.05				1.04	0.99	1.08
DIC	477808.3			457333.0			316951.5			297999.7		

Note. *$p < .05$; **$p < .01$; ***$p < .001$.
OR = odds ratio; SE = standard error; CI = credible interval; SC = social capital; DIC = the Bayesian Deviance Information Criterion.



Note. *$p < .05$

Fig. 1. Interaction terms between interventions and community-level social capital.

be tested in future studies whether the associations we found are causal. Second, we could not obtain detailed data on the salon or volunteering activities, such as the number of participants or content of the activities, from the report by the MHLW. We expect that future studies will reveal what types of social activities are more effective on decreasing frailty and how older adults can be motivated to participate in them. Third, the JAGES modified the original KCL slightly when it incorporated the KCL into its questionnaire (see Appendix Text A1 and Table A2 for more details). The modifications can cause a measurement error in outcomes that are not related to exposure (as non-differential misclassification), but we adjusted for the fixed effects of the year of investigation, and thus believe that this bias was reduced. Fourth, a sample selection bias may exist if respondents are more likely to participate in community-based programs and less likely to be frail than non-respondents. Nevertheless, the response rates in the JAGES are quite high (generally around 70% per wave) compared to other studies involving community-dwelling older adults (Santos-Eggimann et al., 2009) and is one of the strengths of the present study. Finally, participants are limited to those who are physically and cognitively independent. Hence, our findings cannot generalize to those who have been disabled.

5. Conclusions

In summary, the present study found a negative association between the promotion of social activities by LTCI insurers and the likelihood of frailty. The results also suggest that interventions by insurers can even compensate for lack of community-level social capital. It is our hope that this study will motivate local governments to promote community-based strategies for postponement of frailty in community-dwelling older adults.

Authorship contributions

KS conceived the design, performed the statistical analysis, and drafted the manuscript. KK and NK collected the data. TI, RW, NK, IK, and KK revised the manuscript critically. All authors approved the final version of the manuscript. There are no conflicts of interest to declare.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.socscimed.2019.112701.

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ENVIRONMENTAL EPIDEMIOLOGY

Cardiometabolic Profiles and Change in Neighborhood Food and Built Environment Among Older Adults: A Natural Experiment

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Abstract

Background:

The association between neighborhood environment and health may be biased due to confounding by residential self-selection. The displacement of disaster victims can act as a natural experiment that exposes residents to neighborhood environments they did not select, allowing for the study of neighborhood effects on health.

Methods:

We leveraged data from a cohort of older adults 65 years of age or older living in Iwanuma, Japan, located 80 km west of the 2011 Great East Japan Earthquake and Tsunami. Surveys were conducted 7 months before the disaster, as well as 2.5 and 5.5 years afterward, and linked with medical records. We classified each individual's type of exposure to neighborhood environment based on proximity to local food and recreation destinations and walkability.

Results:

Fixed-effect models indicated that change in the exposure type from low to high urban density was associated with increased body mass index (0.46 kg/m^2; 95% confidence interval [CI] = 0.20, 0.73), waist circumference (1.8 cm; 95% CI = 0.56, 3.0), low-density lipoprotein cholesterol (11 mg/dl; 95% CI = 5.0, 17), and decreased high-density lipoprotein cholesterol (−3.1 mg/dl; 95% CI = −5.0, −1.3). We observed similar trends when we analyzed only the individuals who experienced postdisaster relocation to temporary homes.

Conclusions:

Increased proximity to food outlets was simultaneously correlated with greater walkability and accessibility to recreational destinations; however, any protective association of physical activity-

promoting built environment appeared to be offset by proximity to unhealthy food outlets, especially fast-food restaurants and bars.

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Does Laughter Predict Onset of Functional Disability and Mortality Among Older Japanese Adults? The JAGES Prospective Cohort Study

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ABSTRACT

Background: While laughter is broadly recognized as a good medicine, a potential preventive effect of laughter on disability and death is still being debated. Accordingly, we investigated the association between the frequency of laughter and onset of functional disability and all-cause mortality among the older adults in Japan.

Methods: The data for a 3-year follow-up cohort including 14,233 individuals (50.3% men) aged ≥65 years who could independently perform the activities of daily living and participated in the Japan Gerontological Evaluation Study were analyzed. The participants were classified into four categories according to their frequency of laughter (almost every day, 1–5 days/week, 1–3 days/month, and never or almost never). We estimated the risks of functional disability and all-cause mortality in each category using a Cox proportional hazards model.

Results: During follow-up, 605 (4.3%) individuals developed functional disability, identified by new certification for the requirement of Long-Term Care Insurance, and 659 (4.6%) deaths were noted. After adjusting for the potential confounders, the multivariate-adjusted hazard ratio of functional disability increased with a decrease in the frequency of laughter (P for trend = 0.04). The risk of functional disability was 1.42 times higher for individuals who laughed never or almost never than for those who laughed almost every day. No such association was observed with the risk of all-cause mortality (P for trend = 0.39).

Conclusions: Low frequency of laughter is associated with increased risks of functional disability. Laughter may be an early predictor of functional disability later on in life.

Key words: laughter; long-term care; death; cohort study; Japan

INTRODUCTION

Increasing functional disability, defined as difficulty in performing the activities of daily living, is a significantly important public health concern in rapidly aging societies worldwide.[1] Particularly in Japan, one-fourth of its population of 127 million people is now aged ≥65 years.[2] Furthermore, the number of people certified with functional disability has increased by nearly 1.4 times in the past decade, accounting for 17.3% of the Japanese population aged ≥65 years.[3] Identifying the factors for preventing incident functional disability is a critical goal for super-aged societies, including Japan, because age-related functional disability negatively affects an individual's health status, predicts mortality,[4] and increases the healthcare costs associated with long-term care and hospital services.[5,6]

Laughter could potentially be regarded as medicine. Recently, an increasing number of studies have reported the beneficial effects of laughter on several health outcomes among older adults, such as on the cardiovascular functions and diseases and mental health.[7–11] However, studies assessing the association between laughter and functional disability and mortality, while considering the individuals' socioeconomic background, have not been reported. The frequency of laughter can vary according to an individual's socioeconomic status,[12] which is associated with the

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late-life health trajectories.[13] The socioeconomic status can be considered a common cause of the association between laughter and health outcomes. Therefore, by targeting a large general population of community-dwelling older adults, this prospective cohort study aimed to test the hypothesis that low frequency of laughter is associated with a higher risk of onset of functional disability and all-cause mortality when the socioeconomic status is taken into consideration.

METHODS

Study sample

This study was based on the cohort data from the Japan Gerontological Evaluation Study (JAGES),[14] which is an ongoing longitudinal study investigating the factors associated with health and well-being in the community-dwelling adults aged ≥65 years who could independently perform the physical and cognitive activities of daily living. Functional independency was defined as not being certified for Japan's national Long-term Care Insurance system. We used the data of the 2013 wave (from October to December). In the 2013 wave, self-reported questionnaires were mailed to 193,694 community-dwelling elderly adults aged ≥65 years in 30 municipalities; of these, 137,736 individuals responded to the survey (response rate = 71.1%). The questionnaire comprised basic questions and five modules that covered different topics, as follows: module A, nursing care and medical care and lifestyles; module B, oral hygiene, optimism, and subjective health; module C, social capital and history of abuse; module D, subjective quality of life, sleep, and cognitive function; and module E, physical activity. Of the respondents, 21,377 individuals in 23 municipalities in 9 (out of 47) prefectures responded to the basic questions and module B, including questions about laughter, in the questionnaire of the JAGES. Of the eligible sample of 21,377 individuals, 20,714 were successfully associated with the administrative records in 2016, corresponding to a follow-up rate of 96.9%. After excluding 6,481 participants with missing information regarding the frequency of laughter ($n = 958$), annual household income ($n = 3,191$), medical history ($n = 878$), and survey questions on other covariates used in the analysis ($n = 1,454$), we finally analyzed the data of 14,233 participants (men, 7,162; women, 7,071).

Outcomes

The outcomes of the present study were the onset of functional disability and all-cause mortality obtained from the municipal and national databases. The onset of functional disability was determined when an individual was newly certified for Long-term Care Insurance level 2–5,[15,16] which is based on a multistep assessment of functional and cognitive impairments by a qualified investigator and on comments from the family physician.[17] Information regarding the onset of mortality was obtained from the administrative databases of the national Long-term Care Insurance registers. These definitions were used in previous epidemiological studies.[18,19]

Exposure

The daily frequency of laughter was measured based on the response to the following standard single-item question: "How often do you laugh out loud?" The possible item answers were as follows: almost every day, 1–5 days per week, 1–3 days per month, or never or almost never. The 1-year test-retest reliability of the question was reported in a previous study[20]; subsequently, regional and seasonal differences in the daily frequency of laughter among the Japanese men and women were not observed. This item had been used in several previous studies.[8,9,12,21]

Covariates

We included a wide range of covariates in the analyses as potential confounders based on prior literature.[8,9,12,18,21] Information on sex, age, hypertension, diabetes mellitus, smoking habit, alcohol intake, family structure, social participation, depressive symptoms, cognitive function, instrumental activities of daily living (IADL), educational attainment, and equivalent income was obtained from a self-administered questionnaire. Smoking habit and alcohol intake were classified into the following three categories: current, ever, and never. We considered the respondents who answered "Yes" to the question, "Have you ever been diagnosed with hypertension or diabetes mellitus?" as participants with hypertension or diabetes mellitus, respectively. Family structure was assessed through two questions, one related to marital status and the other to number of people living together. The marital status question provided five answer categories (married, bereaved, divorced, never married and other). According to the responses to these questions, family structure was classified into four groups: alone, ≥2 without partner, ≥2 with partner, or ≥2 with no information about marital status. Social participation was defined as the person's involvement in social activities (eg, volunteer group, sports group or club, leisure activity group, senior citizen club, neighborhood association or residents' association, study or cultural group, nursing care prevention or health building, teaching skills or passing on experiences to others, local events). We defined the participants who engaged in one or more of the social activities more than once per week as socially active. To assess the depressive symptoms, we used the 15-item Geriatric Depression Scale; the participants were categorized into the following two groups based on the scores: not depressed (0–4 points) and depressed (≥5 points).[22,23] Cognitive function was assessed through three questions (part of the Kihon Check-list,[24] a basic function checklist in Japanese): First, Do your family or your friends point out your memory loss? Second, Do you make a call by looking up phone numbers? Third, Do you find yourself not knowing today's date? Participants are asked to respond either "negative" (score: 1) or "positive" (score: 0). We divided the participants into the following two groups based on the scores: Decline (1–3 points) and Normal (0 point). Our assessment of IADL was based on a five-item subscale of the Tokyo Metropolitan Institute of Gerontology Higher Competence Scale.[25] We categorized those who had difficulty with at least one item as 'dependent'; others were categorized as 'independent.' Attainment of education and annual equivalent income served as indicators of the socioeconomic status. Attainment of education was evaluated based on the self-reported history of education and was classified into two categories (≤9 years and ≥10 years). The equivalent income was divided into nine categories (≤$14,900, $15,000–19,900, $20,000–24,900, $25,000–29,900, $30,000–34,900, $35,000–39,900, $40,000–45,900, $45,000–49,900, and ≥$50,000).

Statistical analysis

For the demographic characteristics, summary statistics were constructed using frequencies for categorical variables. Linear trends regarding the frequencies of risk factors according to the frequency of laughter categories were tested using logistic regression analysis. Cox proportional hazards model was used to estimate the crude and adjusted hazard ratios (HRs) and their

95% confidence intervals (CIs) for the onset of functional disability and all-cause mortality according to the frequency of laughter. In multivariate adjustment, all covariates (sex, age, hypertension, diabetes mellitus, smoking habit, alcohol intake, marital status, social participation, depressive symptoms, educational attainment, and equivalent income) were included. All statistical analyses were performed using the International Business Machines Corporation Statistical Package for the Social Sciences (SPSS) version 25 statistical software (SPSS, Inc.; Chicago, IL, USA), and two-sided *P*-values <0.05 were considered statistically significant in all cases.

Ethical issues

Our study protocol and informed consent procedure were approved by the Ethics Committee on Research of Human Subjects at Nihon Fukushi University (August 6, 2013, No 13-14).

RESULTS

Table 1 shows the baseline characteristics of the study population according to the frequency of laughter. The likelihood of being female, being socially active, and having 10 years or more of education increased gradually with the increasing frequency of

Table 1. Baseline characteristics of the study population by the frequency of laughter

	Almost every day (n = 6,120)		1–5 days per week (n = 5,440)		1–3 days per month (n = 1,639)		Never or Almost never (n = 1,034)		*P* for trend
	n	%	*n*	%	*N*	%	*N*	%	
Women	3,417	55.8	2,700	49.6	603	36.8	351	33.9	<0.001
Age, years									<0.001[a]
65–69	1,925	31.5	1,683	30.9	468	28.6	262	25.3	
70–74	2,078	34.0	1,632	30.0	465	28.4	293	28.3	
75–79	1,245	20.3	1,198	22.0	387	23.6	220	21.3	
80–84	616	10.1	651	12.0	220	13.4	155	15.0	
≤85	256	4.2	276	5.1	99	6.0	104	10.1	
Hypertension									0.537
Diagnosed	2,779	45.4	2,487	45.7	745	45.5	483	46.7	
Diabetes mellitus									<0.001
Diagnosed	827	13.5	740	13.6	254	15.5	189	18.3	
Smoking habit									<0.001[a]
Current	571	9.3	554	10.2	229	14.0	175	16.9	
Ever	903	14.8	998	18.3	363	22.1	229	22.1	
Never	4,646	75.9	3,888	71.5	1,047	63.9	630	60.9	
Alcohol Intake									<0.001[a]
Current	2,138	34.9	1,995	36.7	677	41.3	393	38.0	
Ever	262	4.3	282	5.2	113	6.9	74	7.2	
Never	3,720	60.8	3,163	58.1	849	51.8	567	54.8	
Family structure									<0.001[a]
Alone	679	11.1	890	16.4	314	19.2	261	25.2	
≥2 without partner	793	13.0	722	13.3	189	11.5	147	14.2	
≥2 with partner	4,608	75.3	3,787	69.6	1,118	68.2	614	59.4	
≥2 without information about marital status	40	0.7	41	0.8	18	1.1	12	1.2	
Social participation									<0.001
Active	2,186	35.7	1,816	33.4	368	22.5	151	14.6	
Depressive symptoms									<0.001
Depressed	872	14.2	1,416	26.0	672	41.0	618	59.8	
Cognitive function									<0.001
Decline	1,871	30.6	1,905	35.0	690	42.1	528	51.1	
Instrumental activities of daily living									<0.001
Dependent	993	16.2	1,018	18.7	391	23.9	332	32.1	
Attainment of education									<0.001
≥10 years	3,835	62.7	3,288	60.4	1,004	61.3	538	52.0	
Equivalent income (10,000$, 1$ = 100 yen)									<0.001[a]
≤1.49	1,439	23.5	1,476	27.1	520	31.7	425	41.1	
1.50–1.99	1,285	21.0	1,296	23.8	406	24.8	228	22.1	
2.00–2.49	1,181	19.3	979	18.0	303	18.5	158	15.3	
2.50–2.99	364	5.9	330	6.1	72	4.4	49	4.7	
3.00–3.49	643	10.5	506	9.3	107	6.5	51	4.9	
3.50–3.99	398	6.5	308	5.7	93	5.7	43	4.2	
4.00–4.49	156	2.5	99	1.8	27	1.6	17	1.6	
4.50–4.99	193	3.2	148	2.7	33	2.0	22	2.1	
≥5.00	461	7.5	298	5.5	78	4.8	41	4.0	

[a]Tested using chi-square test.

laughter. The likelihood of having been diagnosed with diabetes mellitus, being with cognitive decline, being dependent in IADL and being depressed decreased gradually with the increasing frequency of laughter. The frequency of age, smoking habit, alcohol intake, family structure, and equivalent income categories were significantly different across the frequency of laughter categories.

During follow-up (median, 3.3 years), 605 (4.3%) individuals developed functional disability and 659 (4.6%) deaths were noted. The all-cause mortality and functional disability rates were compared according to the daily frequency of laughter using the Kaplan-Meier method. Functional disability and all-cause mortality were more commonly observed among participants with a low frequency of laughter (log-rank test, $P < 0.001$, Figure 1A and log-rank test, $P < 0.001$, Figure 1B, respectively).

Table 2 shows the results of Cox proportional hazards analysis for the association of the frequency of laughter and functional disability and all-cause mortality. In the crude model, significantly inverse associations between the frequency of laughter and functional disability (P for trend <0.001) and all-cause mortality (P for trend <0.001) were observed. These inverse associations remained significant after adjusting for sex and age (functional disability, P for trend <0.001; all-cause mortality, P for trend = 0.001). After adjusting for the abovementioned covariates, the multivariate-adjusted HR of functional disability increased with a decrease in the frequency of laughter (P for trend = 0.04). The risk of developing functional disability was 1.42 times higher for individuals who laughed never or almost never than for those who laughed almost every day (95% CI, 1.10–1.85). However, no

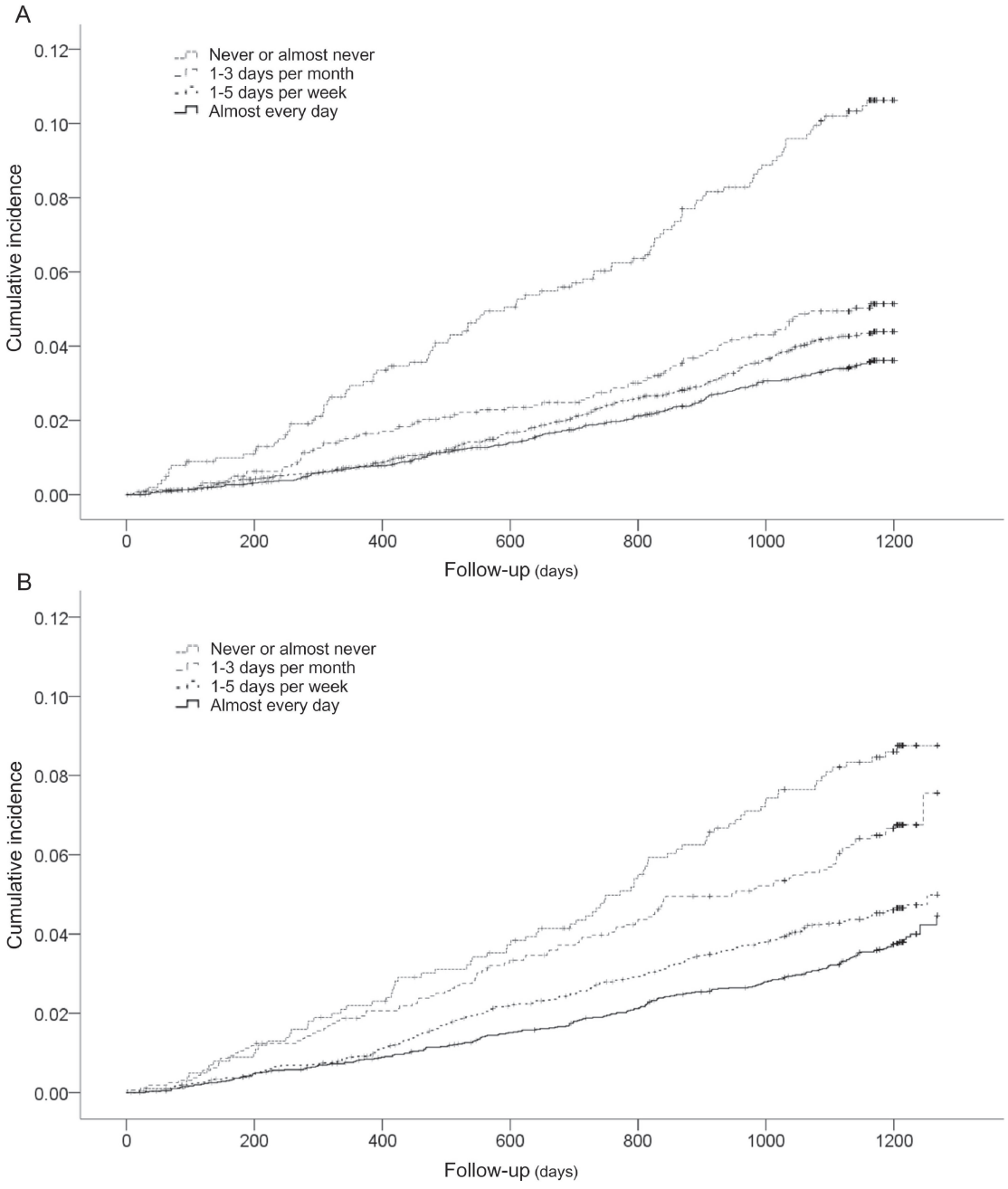

Figure 1. Kaplan-Meier curves showing cumulative incidence of functional disability (A) and all-cause mortality (B) according to the frequency of laughter

Table 2. Likelihood of onset of functional disability and all-cause mortality according to the frequency of laughter

	Almost every day (n = 6,120)	1–5 days per week (n = 5,440)	1–3 days per month (n = 1,639)	Never or Almost never (n = 1,034)	P for trend
Functional disability, n	206	223	78	98	
Crude HR (95% CI)	1.00 (reference)	1.23 (1.02–1.49)	1.45 (1.12–1.88)	2.98 (2.34–3.79)	<0.001
Adjusted HR (95% CI)[a]	1.00 (reference)	1.13 (0.94–1.37)	1.22 (0.94–1.59)	2.14 (1.68–2.74)	<0.001
Adjusted HR (95% CI)[b]	1.00 (reference)	1.04 (0.86–1.26)	0.97 (0.74–1.27)	1.42 (1.10–1.85)	0.039
All-cause mortality, n	226	244	104	85	
Crude HR (95% CI)	1.00 (reference)	1.22 (1.02–1.47)	1.75 (1.38–2.20)	2.29 (1.79–2.94)	<0.001
Adjusted HR (95% CI)[a]	1.00 (reference)	1.10 (0.92–1.32)	1.35 (1.07–1.70)	1.52 (1.18–1.96)	<0.001
Adjusted HR (95% CI)[b]	1.00 (reference)	1.03 (0.86–1.24)	1.13 (0.89–1.44)	1.08 (0.83–1.41)	0.389

CI, confidence interval; HR, hazard ratio.
[a]Adjusted for sex and age.
[b]Adjusted for sex, age, hypertension, diabetes mellitus, smoking, alcohol intake, family structure, social participation, depressive symptoms, cognitive function, instrumental activities of daily living, educational attainment, and equivalent income.

such association was observed with the risk of all-cause mortality (P for trend = 0.39).

DISCUSSION

To the best of our knowledge, this is the first study to comprehensively examine the association between laughter and functional disability and all-cause mortality after carefully controlling for the potential confounders, such as the socioeconomic status. The present prospective cohort study of community-dwelling Japanese older adults revealed an inverse association between the daily frequency of laughter and onset of functional disability, indicating that participants with a lower frequency of laughter were at higher risk of the onset of functional disability. Particularly, laughing never or almost never could increase the risk of functional disability by nearly 50%. In this study, approximately one-fifth of the participants laughed less than once per week; hence, it is reasonable to hypothesize that public health efforts regarding the dissemination of information on the importance of laughter to reduce the future incidence of functional disability predicting mortality among the older adults are warranted.

While published reports indicating the association between the frequency of laughter and functional disability are not currently available, several previous reports revealed that the daily frequency of laughter was associated with the prevalence and incidence of cardiovascular diseases,[8,21] which constitute the second leading cause of functional disability in Japan.[26] Based on our present results being in line with these previous findings, we provide valuable new evidence that the low frequency of laughter itself contributes to the development of functional disability, independent of the established confounders.

There are several plausible mechanisms underlying the association between laughter and functional disability among the older adults. First, laughter might produce physiological changes in various systems of the body,[27] such as improvement of the immune function[28] and stimulation of circulation.[29] In turn, a low frequency of laughter can trigger functional impairments. Second, a high frequency of laughter may be a marker of positive emotions in daily life, which is associated with lower functional limitations.[30] Moreover, laughter-related positive emotions are able to downregulate the cardiovascular aftereffects of negative emotions, which can serve as a buffer against functional disability.[31] Finally, laughter can play a role in buffering the effects of stress. For example, stimulated and spontaneous laughter is reported to decrease salivary cortisol level, a biomarker of stress.[32,33] Thus, individuals with a higher frequency of laughter may cope more effectively with stress than individuals with a lower frequency of laughter, which may moderate the adverse effects of stress on the individuals' physical health.

Regarding all-cause mortality, our study revealed that age- and sex-adjusted HR of all-cause mortality increased with a decrease in the daily frequency of laughter, but this inverse association was insignificant after adjusting for all covariates. Meanwhile, a recent previous study[21] reported a significant association between the daily frequency of laughter and all-cause mortality. This discrepancy is possibly attributed to the differences in the study settings (nine prefectures covering a wide area in Japan vs one prefecture), participants (a general population of community-dwelling older adults vs community-based annual health checkup examinees), and controlling for the confounding effects of the socioeconomic status (adjusted vs unadjusted). The present study attempted to reduce the degree of selection bias and potential confounding effects as much as possible. In contrast, both studies included a limited number of mortality events during relatively short periods of time, namely 3–5 years. Thus, further long-term follow-up studies are warranted to elucidate the association between the daily frequency of laughter and onset of mortality.

The primary strengths of the present study are its prospective cohort design, large sample size, population-based sampling, and control for potential confounding factors. In contrast, a limitation of the study was that we evaluated the daily frequency of laughter using a single-item self-reported question. The perceived frequency of laughter may be different from the actual frequency; hence, it may be plausible that less healthy individuals are more likely to not report their frequency of laughter, possibly leading to an underestimation of the association between laughter and health outcomes. Additionally, it is unclear whether laughter itself can prevent the onset of functional disability and mortality. Therefore, further studies are required to precisely identify the causal inference using observational data[34] because random assignment of the daily frequency of laughter and long-term follow-up of the randomized participants to collect the data on number of onset events are difficult in the real-world setting.

In conclusion, the present study revealed that community-dwelling older Japanese who do not laugh much in daily life are at a higher risk of the onset of functional disability, suggesting that the frequency of laughter is potentially considered an early indicator of late-life functional disability.

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RESEARCH Open Access

Cooking skills related to potential benefits for dietary behaviors and weight status among older Japanese men and women: a cross-sectional study from the JAGES

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Abstract

Background: Poor cooking skills have been linked to unhealthy diets. However, limited research has examined associations of cooking skills with older adults' health outcomes. We examined whether cooking skills were associated with dietary behaviors and body weight among older people in Japan.

Methods: We used cross-sectional data from the 2016 Japan Gerontological Evaluation Study, a self-report, population-based questionnaire study of men ($n = 9143$) and women ($n = 10,595$) aged ≥65 years. The cooking skills scale, which comprises seven items with good reliability, was modified for use in Japan. We calculated adjusted relative risk ratios of unhealthy dietary behaviors (low frequency of home cooking, vegetable/fruit intake; high frequency of eating outside the home) using logistic or Poisson regression, and relative risk ratios of obesity and underweight using multinomial logistic regression.

Results: Women had higher levels of cooking skills, compared with men. Women with a moderate to low level of cooking skills were 3.35 (95% confidence interval [CI]: 2.87–3.92) times more likely to have a lower frequency of home cooking and 1.61 (95% CI: 1.36–1.91) times more likely to have a lower frequency of vegetable/fruit intake, compared with women with a high level of cooking skills. Men with a low level of cooking skills were 2.56 (95% CI: 2.36–2.77) times more likely to have a lower frequency of home cooking and 1.43 (95% CI: 1.06–1.92) times more likely to be underweight, compared with men with a high level of cooking skills. Among men in charge of meals, those with a low level of cooking skills were 7.85 (95% CI: 6.04–10.21) times more likely to have a lower frequency of home cooking, 2.28 (95% CI: 1.36–3.82) times more likely to have a higher frequency of eating outside the home, and 2.79 (95% CI: 1.45–5.36) times more likely to be underweight, compared with men with a high level of cooking skills. Cooking skills were unassociated with obesity.

Conclusions: A low level of cooking skills was associated with unhealthy dietary behaviors and underweight, especially among men in charge of meals. Research on improving cooking skills among older adults is needed.

Keywords: Cooking skill, Home cooking, Eating out, Vegetable and fruit intake, Obesity, Underweight

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Background

There are increasing calls to return to home cooking to prevent poor diets and chronic diet-related diseases [1]. A systematic review has reported the dietary benefits of eating home-cooked meals, including greater consumption of fruits and vegetables, enhanced nutrient intake, and higher diet quality [2]. A recent cross-sectional study showed that eating home-cooked dinners was associated with greater dietary guideline compliance, without significantly increasing food expenditures [3]. Although studies related to the effects of home cooking on health outcomes are limited, a recent large population-based study in the United Kingdom showed that more frequent consumption of home-cooked meals was associated with a greater likelihood of having normal weight and body fat status [4]. Furthermore, a cohort study targeting older people in Taiwan demonstrated that older adults who cooked more than five times per week had approximately 40% lower risk of death, compared with those who did not cook [5]. The study also showed a dose–response relationship, meaning that the risk of death decreased as the frequency of home cooking increased. Despite the benefits of home cooking, the consumption of home-cooked meals has declined and the consumption of out-of-home foods, such as fast food and convenience food, has increased in recent decades in developed countries [6, 7].

Cooking skills are one important modifiable factor that can encourage people to cook [2]. In addition to increasing the frequency of home cooking, strengthening people's cooking skills can improve their diet quality. For example, cross-sectional studies have shown an association between high levels of cooking skills and lower consumption of ready meals, convenience food, and ultra-processed food among adults [8–10]. Intervention studies have also shown improving cooking skills to increase cooking confidence and consumption of vegetables and fruits [11, 12]. Most existing studies have focused on dietary benefits among adults, and limited work has examined the associations between cooking skills and health outcomes among older adults.

Population aging is increasing dramatically, and the percentage of the world's population aged over 60 years is projected to nearly double from 12% in 2015 to 22% in 2050 [13]. Overall, older adults do not meet the recommendations for a healthy diet [14]. Physiological, social, economic, and psychological factors affect older people's food choices. Physiological factors, such as age-related decline in taste and smell, can lead to decreased appetite and poor dietary habits [15]. Social factors, including lower social engagement and living alone, are also associated with poor diet quality [15, 16]. Economic factors such as low income and retirement can negate older people's ability to meet their nutritional needs [17, 18]. Finally, psychological factors including wellbeing and depression are also associated with eating behaviors [16]. However, although cooking skills are a fundamental factor in preparing meals, the effects of cooking skills on dietary behaviors do not seem to have been evaluated among older adults. A systematic review demonstrated associations between culinary interventions and improved dietary factors, including attitudes, self-efficacy, and healthy dietary intake among adults [19]. Focusing on cooking skills as a modifiable factor among older adults is an innovative approach.

The rationales described above indicate that having sufficient cooking skills may be important for healthy aging. More older adults live alone, compared with other age groups: In 43 developing countries, only 1.6% of people were found to live alone overall, compared with 8.8% of older adults [20]. In Japan, most older people live alone or with their spouses [21]. Thus, older adults are faced with the task of preparing own meals. Because of changes in living arrangements or spouses becoming unable to cook, the person responsible for cooking at home may change in older age. For example, a widowed man may be in charge of cooking for the first time. Because it is mainly women who are in charge of preparing meals, men have been found to be less confident in their cooking and to have lower levels of cooking skills [9, 22]. Therefore, men, especially widowed men or men whose spouses are unable to cook, may be at risk of diet-related problems because of their poor cooking skills. To our knowledge, no study has examined the associations between cooking skills and health outcomes among older people who are in charge of meals.

One reason for the limited evidence relating to cooking skills may be the difficulty of assessing cooking skills. Cooking skills have been defined as a set of mechanical or physical skills used in meal preparation, such as chopping, mixing, and heating basic ingredients, as well as conceptual skills related to understanding how food will react when cooked [23]. In addition to the various aspects of cooking skills, the cooking skills required vary depending on culture: For example, cooking methods (e.g., grilling, steaming, stewing, and stir-frying) differ by culture. Several methods have been used to measure cooking skills, but there are few validated and reliable measures of cooking skills [23]. Hartmann et al. conducted a test-retest analysis and designed a reliable cooking skills scale comprising seven items related to the ability to prepare different foods that is applicable to most European cultures [9]. Because this scale rates the ability to prepare general food groups (e.g., bread), it is more versatile than scales that rate the ability to prepare specific meals (e.g., spaghetti Bolognese). Therefore, for the present study, we modified this scale for application in a Japanese population. The first aim of our study was to assess the reliability of this scale in a large-scale

Japanese population-based study. The second aim was to examine the associations of cooking skills with the frequency of home cooking, the frequency of eating outside the home, the frequency of vegetable/fruit consumption, and body weight status.

Methods

Study design and participants

The Japan Gerontological Evaluation Study (JAGES), a large nation-wide research project on aging, was established in 2010 to evaluate the social determinants of healthy aging among older people in Japan [24, 25]. We used data from the 2016 JAGES, which covered 39 municipalities across Japan and was administered to community-dwelling older adults who were physically and cognitively independent (i.e., without functional disabilities, defined as not being certified as eligible to receive long-term public care insurance system services [26]). From October 2016 to January 2017, self-report questionnaires were mailed to 279,661 older adults aged ≥65 years. The survey was conducted using random sampling in 22 large municipalities and was administered to all eligible residents in 17 small municipalities. A total of 196,438 participants returned the questionnaire (response rate: 70.2%). In some municipalities, recipients receiving long-term public care insurance benefits were included in the survey by request of the local government, so the target sample was 180,021 older adults, after excluding those who received these benefits. One-eighth of the sample ($N = 22,219$) were randomly selected to receive a survey module on cooking skills. The present analysis was carried out using data for 19,738 participants (9143 men and 10,595 women), after the following exclusions: participants with missing information on gender ($N = 2$); participants who did not complete the questions related to height and weight ($N = 660$) or dietary behaviors (frequency of home cooking, eating outside the home, and vegetable/fruit intake) ($N = 1475$); participants with missing data on the cooking skills scale ($N = 145$); and participants who were included in this study accidentally who reported limitations in activities of daily living ($N = 199$) to ensure that the sample was actually physically and cognitively independent. Limitations in activities of daily living were assessed with the Independence in Activities of Daily Living index [27] using the following questionnaire item: "Do you need any nursing care or assistance from someone in your daily life?" We excluded participants who answered "I need and receive nursing care or assistance." Participants were informed that participation in the study was voluntary and that completing and returning the questionnaire indicated their consent to participate in the study. The JAGES protocol was approved by the Ethics Committee in Research of Human Subjects at the National Center for Geriatrics and Gerontology (No. 992) and Chiba University Faculty of Medicine (No. 2493).

Body weight status and dietary behaviors

Participants reported their height in centimeters and weight in kilograms. Body mass index (BMI) was calculated as weight divided by the square of height (kg/m^2). We defined underweight as having a BMI < 18.5 kg/m^2 and obesity as having a BMI ≥ 27.5 kg/m^2, following the suggested cutoff points for Asians [28]. The evaluated dietary behaviors were the frequency of home cooking, eating outside the home, and vegetable/fruit intake. The frequency of home cooking was assessed using the question "How often do you cook by yourself? Do not include ready-to-eat food" (responses: *more than five times a week*, *three to five times a week*, *one to two times a week*, *less than once a week*, and *never*). Respondents who cooked less than two times a week were categorized as having a low cooking frequency for women because more than three times a week has been shown to predict survival among older women [5]. For men, respondents who never cooked were categorized as having a low cooking frequency because more than half of the men indicated that they never cooked (Table 1). The frequency of eating outside the home was assessed using the question "How often do you eat outside the home?" The responses for this item were the same as those for the frequency of home cooking. Respondents who ate outside the home more than three times a week were categorized as having a high frequency of eating outside the home because eating outside the home more than three times a week has been shown to be related to higher BMI and lower serum concentrations of nutrients [29]. The frequency of vegetable and fruit intake was assessed using the question "How often did you eat vegetables and fruits over the past month?" (responses: *not at all*, *less than once a week*, *once a week*, *two to three times a week*, *four to six times a week*, *once a day*, and *at least twice a day*) [30, 31]. Respondents who ate vegetables and fruits less than once a day were categorized as having a low frequency of vegetable and fruit intake. This cutoff point was defined by prevalence to be under 25% of subjects included (Table 1) because being in the lowest quartile for vegetable and fruit intake has been shown to be associated with poor health outcomes [32–34].

Cooking skills

As mentioned above, based on the cooking skills scale for European cultural regions [9], we adapted Hartmann's a cooking skills scale for use in Japanese populations. In Japan, a typical meal—known as *ichi-ju san-sai*—consists of a staple food (such as rice), a soup (usually miso), and three dishes (one main dish and two side

Table 1 Characteristics of older Japanese men and women by level of cooking skills ($n = 19,378$)

	Males ($n = 9143$)						Females ($n = 10,595$)				
	Total		Cooking skill				Total		Cooking skill		
	n	%	High %	Middle %	Low %	*p*-value	n	%	High %	Middle/Low %	*p*-value
Cooking skill											
High	4751	52.0	100	0	0		9968	94.1	100.0	0	
Middle	3269	35.8	0	100	0		498	4.7	0	79.4	
Low	1123	12.3	0	0	100		129	1.2	0	20.6	
Age (years)											
65–69	2855	31.2	32.7	29.8	29.2	< 0.001	3269	30.9	31.7	18.0	< 0.001
70–74	2510	27.5	26.9	29.1	25.1		2893	27.3	27.8	19.9	
75–79	2059	22.5	22.9	22.3	21.4		2393	22.6	22.8	19.8	
≥ 80	1719	18.8	17.5	18.8	24.3		2040	19.3	17.8	42.3	
Education (years)											
Low (≤9)	2626	28.7	28.2	28.1	32.7	0.002	3614	34.1	33.3	46.4	< 0.001
Middle (10–12)	3461	37.9	36.8	39.4	37.9		4638	43.8	44.2	37.0	
High (≥13)	2981	32.6	34.1	31.8	28.8		2198	20.7	21.1	14.7	
Other/Missing	75	0.8	0.9	0.8	0.6		145	1.4	1.3	1.9	
Annual income (million yen)											
Low (< 2.00)	3485	38.1	37.5	38.6	39.4	0.215	4110	38.8	38.5	43.1	< 0.001
Middle (2.00–3.99)	3279	35.9	35.9	36.6	33.3		3049	28.8	29.3	21.1	
High (≥4.00)	924	10.1	10.6	9.3	10.6		885	8.4	8.5	5.9	
Missing	1455	15.9	16	15.4	16.7		2551	24.1	23.7	30.0	
Marital status											
Married	7788	85.2	81.6	88.0	92.0	< 0.001	6497	61.3	62.4	44.7	< 0.001
Widowed	631	6.9	8.5	5.4	4.3		3097	29.2	28.3	43.9	
Divorced	321	3.5	4.7	2.6	1.2		513	4.8	4.8	5.1	
Single	257	2.8	3.4	2.6	1.0		307	2.9	2.8	4.1	
Other/Missing	146	1.6	1.8	1.3	1.5		181	1.7	1.7	2.2	
Under medical treatment											
Cancer (Yes)	450	4.9	5.1	4.5	5.7	0.53	355	3.4	3.3	4.3	0.35
Heart disease (Yes)	1219	13.3	13	13.6	14.2	0.84	713	6.7	6.5	9.7	0.008
Stroke (Yes)	385	4.2	3.5	4.5	6.5	< 0.001	184	1.7	1.6	4.1	< 0.001
Diabetes mellitus (Yes)	1484	16.2	16.6	15.3	17.4	0.47	1010	9.5	9.5	10.4	0.69
Hypertension (Yes)	3913	42.8	42.1	43.5	43.8	0.66	4391	41.4	41.0	48.2	0.002
Hyperlipidemia (Yes)	933	10.2	10.3	10.4	9.4	0.92	1658	15.6	15.8	13.2	0.19
Main way of preparing meals											
Cook by yourself	1283	14.0	22.2	6.1	2.2	< 0.001	8714	82.2	84.0	54.9	< 0.001
Family member cook	6785	74.2	65.1	82.5	88.5		977	9.2	7.9	30.3	
Buy cooked meals	307	3.4	2.8	4.3	2.8		132	1.2	1.1	4.1	
Use home-delivery services	81	0.9	0.9	0.7	1.4		46	0.4	0.4	1.0	
Other/Missing	687	7.5	8.9	6.3	5.1		726	6.9	6.7	9.7	
Frequency of home cooking (n/week)											
≥ 5 /week	1310	14.3	23.3	5.8	1.2	< 0.001	8762	82.7	84.6	51.8	< 0.001
3–4 /week	757	8.3	12.5	4.6	1.1		902	8.5	8.3	11.8	

Table 1 Characteristics of older Japanese men and women by level of cooking skills ($n = 19,378$) *(Continued)*

	Males ($n = 9143$)						Females ($n = 10,595$)				
	Total		Cooking skill				Total		Cooking skill		
	n	%	High	Middle	Low	*p*-value	n	%	High	Middle/Low	*p*-value
			%	%	%				%	%	
1–2 /week	1002	11	15.3	7.7	2.0		366	3.5	3.2	8.1	
< 1 /week	1157	12.7	15.2	12.4	2.8		199	1.9	1.5	7.2	
Never	4917	53.8	33.7	69.6	92.9		366	3.5	2.3	21.1	
Frequency of eating outside the home (n/week)											
≥ 5 /week	242	2.6	2.6	2.3	3.7	< 0.001	103	1.0	0.9	1.4	0.001
3–4 /week	462	5.1	5.0	5.4	4.2		268	2.5	2.6	2.1	
1–2 /week	1450	15.9	16.9	15.6	12.3		1268	12.0	12.1	10.4	
< 1 /week	3773	41.3	41.3	41.9	39.2		4297	40.6	41.0	34.1	
Never	3216	35.2	34.2	34.7	40.7		4659	44.0	43.5	52.0	
Frequency of vegetable/fruit intake (n/day)											
≥ 1 /day	6625	72.5	73.3	70.6	74.4	0.008	9052	85.4	86.0	75.9	< 0.001
< 1 /day (low frequency)	2518	27.5	26.7	29.4	25.6		1543	14.6	14.0	24.1	
Body weight status (BMI, kg/m^2)											
Underweight (< 18.5)	428	4.7	4.1	5.1	5.8	0.04	988	9.3	9.2	11.8	0.08
Normal (18.5–27.4)	8044	88.0	88.1	88.0	87.4		8833	83.4	83.5	81.5	
Obesity (≥ 27.5)	671	7.3	7.8	6.9	6.9		774	7.3	7.3	6.7	

BMI body mass index

dishes) [35]. The basic Japanese cooking methods—*Gohou* (five methods)—are raw food, boiling, grilling, steaming, and frying [36]. We adopted stewing instead of steaming to reflect contemporary cooking practices [37]. Therefore, we included these elements and designed the following seven items for the Japanese version of the cooking skills scale: "How do you assess your overall cooking skills?"; "Can you peel fruits and vegetables?"; "Can you boil eggs and vegetables?"; "Can you grill fish?"; "Can you make stir-fried meat and vegetables?"; "Can you make miso soup?"; and "Can you make stewed dishes?" Participants were asked to evaluate their own cooking skills on a six-point scale (ranging from 1 for *unable* to 6 for *very well*). Cronbach's α for these seven items was 0.96. Cronbach's α was calculated using an unstandardized approach for respondents answering five or more of the seven items. The mean of the seven items was calculated for each respondent to reflect their overall cooking skills; the midpoint was 3.5, and a high score meant that the respondent had high confidence in their cooking skills (Table 2). The mean cooking skills score was divided into three categories—high (> 4.0), middle (2.1–4.0), and low (≤ 2.0)—to examine the associations of cooking skills with body weight status and dietary behaviors. For women, because the distribution of the cooking skills score was skewed to the left (leaning towards higher scores), the middle and low groups were merged into one category. Therefore, women were classified into two cooking skills categories: high (> 4.0) and middle/low (≤ 4.0).

Person in charge of meal selection

Participants were asked "In what way are your daily meals mainly prepared?" The responses to this item were as follows: *cook by myself*, *a family member cooks*, *buy packaged lunches or cooked meals*, *use catering or home-delivery services*, and *other*. Participants except for those who reported that a family member did the cooking were defined as being in charge of preparing or selecting meals.

Covariates

Covariates were assessed using the self-report questionnaire. Age was divided into four categories (65–69, 70–74, 75–79, and ≥ 80 years). The duration of education was divided into three categories (≤ 9 years, 10–12 years, and ≥ 13 years). Annual household income was adjusted for household size, dividing the household income by the square root of the number of people in the household. This variable was then divided into three categories (< 2.00, 2.00–3.99, and ≥ 4.00 million yen). Marital status was divided into five categories (married, widowed, divorced, single, and other). To assess comorbidity, the participants were asked whether they were currently under medical treatment for any of the following conditions (multiple responses were allowed): cancer, heart

disease, stroke, hypertension, diabetes mellitus, and hyperlipidemia. Covariates with missing data were categorized as "missing."

Statistical analysis

The analyses were stratified by gender because a previous study reported different associations between cooking skills and dietary behaviors by gender and distinct patterns of potential confounders for men and women [9]. First, participants were stratified by cooking skill level, and differences between groups were tested using Pearson's chi-squared tests. Second, multiple comparisons for the cooking skills scale were analyzed using the mixed linear model procedure to examine which cooking skills participants rated as difficult. The model adjusted for age, education, annual normalized household income, marital status, and medical treatment (cancer, heart disease, stroke, diabetes mellitus, hypertension, and hyperlipidemia), and peeling was used as the reference category. Participant identification code was included as a random effect. Third, we calculated adjusted odds ratios with 95% confidence intervals (CIs) of high frequency of eating outside the home using logistic regression. For low frequency of home cooking and vegetable/fruit intake, we calculated adjusted prevalence ratios (APRs) with 95% CIs using Poisson regression because participants with low frequencies of home cooking and vegetable/fruit intake were not uncommon, so the odds ratios derived from logistic regression would have been unable to approximate the prevalence ratio [38, 39]. For the association with weight status, we calculated adjusted relative risk ratios (ARRRs) with 95% CIs of underweight and obesity using multinomial logistic regression, with the body weight category of BMI of 18.5–27.4 kg/m^2 as the reference category. The models were adjusted for the following potential confounding factors: age, education, annual normalized household income, and medical treatment for cancer, heart disease, stroke, hypertension, diabetes mellitus, and hyperlipidemia. Participants with missing data on the covariates were included in the analysis. All analyses were conducted using Stata, Version 14 (Stata Statistical Software: Release 14. College Station, TX: StataCorp LP).

Results

The participants' characteristics are summarized in Table 1. A total of 46% of the participants were men, about 20% were aged over 80 years, 30% had under 9 years of education, and 40% had annual incomes below two million yen. Of the male respondents, about 10% were widowed or divorced. When cognitive function was assessed with three items from the Kihon Checklist–Cognitive Function scale, for which predictive validity for dementia incidence has previously been confirmed [40], only 0.9% of participants had three cognitive complaints. The majority of women (94.1%) were classified as having a high level of cooking skills (Table 1). For men, the level of cooking skills was classified as high for 52.0%, middle for 35.8%, and low for 12.3%. For women, 8.9% cooked less than two times a week, 3.5% ate out more than three times a week, 14.6% ate vegetables/fruits less than once a day, 9.3% were underweight, and 7.3% were obese. For men, 53.8% never cooked, 7.7% ate out more than three times a week, 27.5% ate vegetables/fruits less than once a day, 4.7% were underweight, and 7.3% were obese. Women with middle/low-level cooking skills tended to be older, have a low level of education, have low income, not be married, and list a family member as the main meal preparer (Table 1). For men, in addition to being older, having a low level of education, and having a family member as the main meal preparer, men who were married tended to have a low level of cooking skills (Table 1).

The mean cooking skills score was higher for women (5.6 points) than for men (4.1 points) ($t(19736) = -99.6$, $p < 0.001$) (Table 2). For psychometric testing, one factor with an eigenvalue over 1 was found, and this accounted for 80.5% of the variance. All factor loadings were 0.8 or higher. Men rated stewing and stir-frying as more difficult than peeling. Although women had statistically significant differences between the assessed cooking skills, in terms of substantive significance, they rated all the methods assessed on the cooking skills scale as being of similar difficulty (Table 2).

There were gender differences in the associations of cooking skills with unhealthy dietary behaviors and body weight status (Table 3). Women with a middle/low level of cooking skills were 3.35 times (95% CI: 2.87–3.92) more likely to have a lower frequency of home cooking and 1.61 (95% CI: 1.36–1.91) times more likely to have a lower frequency of vegetable/fruit intake, compared with women with a high level of cooking skills. As for weight status, women with a middle/low level of cooking skills were 1.29 (95% CI: 0.99–1.67) times more likely to be underweight, compared with women with a high level of cooking skills. For men, compared with those with a high level of cooking skills, men with a middle or low level of skill were 1.98 (95% CI: 1.86–2.11) times more likely and 2.56 (95% CI: 2.36–2.77) times more likely, respectively, to have a lower frequency of home cooking. Regarding eating outside the home, compared with men with a high level of cooking skills, men with a low level of cooking skills were 1.30 (95% CI: 1.01–1.67) times more likely to have a higher frequency of eating outside the home. There was a significant association with a low frequency of vegetable/fruit intake only among men with a middle level of cooking skills (APR: 1.15, 95% CI: 1.06–1.26). As for weight status, compared with men with a high level of cooking skills, men with middle or

Table 2 Cooking skills among older Japanese men ($n = 9143$) and women ($n = 10,595$)

Items	Males				Females			
	mean	SD	Coef	*p*-value	mean	SD	Coef	*p*-value
Overall cooking skills	3.15	1.53	−1.60	< 0.001	4.99	1.12	−0.77	< 0.001
Able to peel fruits and vegetables	4.75	1.44	reference		5.76	0.74	reference	
Able to boil eggs and vegetables	4.58	1.56	−0.17	< 0.001	5.78	0.73	0.02	0.007
Able to grill fish	4.24	1.72	−0.50	< 0.001	5.70	0.86	−0.06	< 0.001
Able to make stir-fried meat and vegetables	4.04	1.76	−0.70	< 0.001	5.72	0.82	−0.04	< 0.001
Able to make miso soup	4.16	1.77	−0.59	< 0.001	5.74	0.80	−0.02	0.001
Able to make stewed dishes	3.43	1.81	−1.32	< 0.001	5.72	0.82	−0.05	< 0.001
Cooking skill scale	4.05	1.42			5.63	0.74		

Multiple comparisons between cooking skills scale were analyzed using the mixed linear models procedure adjusted for age, education, annual normalized household income, marital status and medical treatment (cancer, heart disease, stroke, diabetes mellitus, hypertension and hyperlipidemia). Participant identification code was included as a random effect

low skill levels were 1.29 (95% CI: 1.04–1.60) times more likely and 1.43 (95% CI: 1.06–1.92) times more likely, respectively, to be underweight. There was no significant association between cooking skills and obesity for either men ($p = 0.33$) or women ($p = 0.40$). Using the cutoff point of BMI ≥ 23.0 kg/m^2 as overweight, we found that a low level of cooking skills was not associated with an increased risk of overweight (Supplementary Table 1).

Next, we focused on men in charge of meals. Over 90% of women ($n = 9618$) but only 26% of men ($n = 2358$) were in charge of daily meals. In contrast to men not in charge of preparing meals, most men in charge of meals rated their cooking skills as high (Supplementary Table 2). Men in charge of meals tended to have low levels of education and low income and to be unmarried (e.g., widowed or divorced) (Supplementary Table 2). When the associations with unhealthy dietary behaviors and weight status were examined for men in charge of meals, the effect size increased (Table 4). Compared with men with a high level of cooking skills, men with middle- or low-level cooking skills were 4.22 (95% CI: 3.42–5.21) times more likely and 7.85 (95% CI: 6.04–10.21) times more likely, respectively, to have a lower frequency of home cooking (Table 4). Regarding eating outside the home, compared with men with a high level of cooking skills, men with a low level of cooking skills were 2.28 (95% CI: 1.36–3.82) times more likely to have a higher frequency of eating outside the home. In relation to low frequency of vegetable/fruit intake, the APR for men with a middle level of cooking skills was 1.32 (95% CI: 1.15–1.53). Furthermore, compared with men with a high level of cooking skills, men with middle or low skill levels were 1.59 (95% CI: 1.04–2.45) times more likely and 2.79 (95% CI: 1.45–5.36) times more likely, respectively, to be underweight.

Table 3 Adjusted prevalence/odds ratios/relative risk ratios of unhealthy eating behaviors, underweight, and obesity by level of cooking skills among older Japanese men ($n = 9203$) and women ($n = 10,847$)

		Low frequency of home cooking[a]	High frequency of eating outside the home[b]	Low frequency of vegetable and fruit intake[c]	Underweight[d]	Obesity[e]
		APR (95%CI)	AOR (95%CI)	APR (95%CI)	ARRR (95%CI)	ARRR (95%CI)
Men						
Cooking skill	High	ref	ref	ref		ref
	Middle	**1.98 (1.86–2.11)**	1.15 (0.97–1.36)	**1.15 (1.06–1.26)**	**1.29 (1.04–1.60)**	0.89 (0.75–1.06)
	Low	**2.56 (2.36–2.77)**	**1.30 (1.01–1.67)**	1.04 (0.91–1.18)	**1.43 (1.06–1.92)**	0.88 (0.68–1.14)
Women						
Cooking skill	High	ref	ref	ref		ref
	Middle-Low	**3.35 (2.87–3.92)**	0.97 (0.62–1.52)	**1.61 (1.36–1.91)**	1.29 (0.99–1.67)	0.87 (0.62–1.21)

AOR adjusted odds ratio, *APR* adjusted prevalence ratio, *ARRR* adjusted relative risk ratio, *BMI* body mass index, *CI* confidence interval
[a]Low frequency of home cooking: frequency of home cooking ≤2 times/week for women and 0 times/week for men
[b]High frequency of eating outside the home: frequency of eating outside the home ≥3 times/week
[c]Low frequency of vegetable and fruit intake: frequency of vegetable and fruit intake < 1/day
[d]Underweight: BMI < 18.5 kg/m^2
[e]Obesity: BMI ≥ 27.5 kg/m^2
The models were adjusted for age, education, annual normalized household income, marital status, and medical treatment (cancer, heart disease, stroke, diabetes mellitus, hypertension, and hyperlipidemia)

Table 4 Adjusted prevalence ratios/relative risk ratios of low frequency of vegetable/fruit intake and home cooking, underweight, and obesity by cooking skills level among older Japanese men in charge of meals ($n = 2370$)

		Low frequency of home cooking[a]	High frequency of eating out[b]	Low frequency of vegetable and fruit intake[c]	Underweight[d]	Obesity[e]
		APR (95%CI)	AOR (95%CI)	APR (95%CI)	ARRR (95%CI)	ARRR (95%CI)
Men in charge of cooking						
Cooking skill	High	ref		ref	ref	ref
	Middle	**4.22 (3.42–5.21)**	**1.63 (1.22–2.17)**	**1.32 (1.15–1.53)**	**1.59 (1.04–2.45)**	0.91 (0.63–1.32)
	Low	**7.85 (6.04–10.21)**	**2.28 (1.36–3.82)**	1.12 (0.84–1.50)	**2.79 (1.45–5.36)**	0.59 (0.25–1.39)

AOR adjusted odds ratio, *APR* adjusted prevalence ratio, *ARRR* adjusted relative risk ratio, *BMI* body mass index, *CI* confidence interval
[a]Low frequency of home cooking: frequency of home cooking 0 times/week
[b]High frequency of eating outside the home: frequency of eating outside the home ≥3 times/week
[c]Low frequency of vegetable and fruit intake: frequency of vegetable and fruit intake < 1/day
[d]Underweight: BMI < 18.5 kg/m^2
[e]Obesity: BMI ≥ 27.5 kg/m^2
The models were adjusted for age, education, annual normalized household income, marital status, and medical treatment (cancer, heart disease, stroke, diabetes mellitus, hypertension, and hyperlipidemia)

Discussion

To the best of our knowledge, this is the first study to examine the associations of cooking skills with unhealthy dietary behaviors and weight status by gender and meal preparer status among older adults. Using an adapted version of an existing cooking scale for use in Japanese populations, we confirmed that women had higher levels of cooking skills than did men and that the associations of cooking skills with dietary behaviors and weight status differed by gender. For both men and women, a low or middle/low level of cooking skills was associated with a low frequency of home cooking. Having low- or middle/low-level cooking skills was found to be significantly associated with high frequency of eating outside the home and with being underweight for men but not for women. The association between low or middle/low level of cooking skills and low frequency of vegetable/fruit intake was found for both men and women, but among men there was no dose–response relationship. The associations of low level of cooking skills with unhealthy dietary behaviors and underweight status were especially pronounced among men in charge of meals. Cooking skills were unassociated with obesity among both women and men.

In this study, a cooking skills scale for use in Japanese populations was designed with consideration of basic Japanese cooking methods and typical meals. Although we did not confirm the validity of this newly designed cooking skills scale by objective assessment, we were able to obtain plausible results, with the same trends observed with the original cooking skills scale for European populations [9]. Our cooking skills scale had appropriate internal consistency (Cronbach's $\alpha = 0.96$) and showed higher values for women and those with higher education levels, which is consistent with previous findings [9, 41]. This result also supports previous findings of a gender difference in confidence in cooking skills indicating that women are more confident in their cooking skills than are men [9, 22, 42]. The differences in cooking skills by gender and educational attainment among Japanese older adults may be explained by opportunities to learn cooking skills in school. In Japan, cooking education in schools was conducted exclusively for women until 1989; therefore, the men in this study (born before 1958) had less opportunity to learn cooking in school [43]. Another factor is that older age is associated with a stronger belief in the gender role ideology holding that men should work outside the home and women should do housework inside the home. In earlier years, there was even a cultural idea that men should not so much as enter the kitchen. This idea is reflected in the saying "*Danshi-chubo-ni-hairazu*" ("A man would be ashamed to be found in the kitchen") [44]. However, men's mean (SD) cooking skills score of 4.1 (1.42) was higher than the midpoint of 3.5, indicating that older Japanese men have above-average confidence in their cooking skills. In line with previous studies on adults showing that levels of cooking skills tend to be high in multiple-person households [8, 9], we found that women's cooking skills were higher when they were married than when they were not. However, in contrast, men's cooking skills were higher when they were not married (e.g., widowed or divorced). This result is intuitive because unmarried men do not have a spouse who is responsible for the cooking. We speculate that unmarried women have a moderate level of cooking skills because they were taught to cook in home economics classes and by their mothers, but their cooking skills may not have continued to improve because there was no need to cook for another person. Interventions earlier in the life course, such as at retirement, may be effective because men have a high risk of unhealthy eating behavior caused by their poor cooking skills if they are later widowed or divorced.

We included five basic cooking methods in the cooking skills scale, finding that men rated stewing and stir-frying as more difficult, compared with peeling and boiling. A previous study that examined eight cooking

methods in the United Kingdom showed that men were more confident about boiling, compared with stewing or stir-frying [42]. This result is plausible because stewing and stir-frying require adjusting the level of heat and adding seasoning to prepare the dish properly. In interventions targeting men, it might be most beneficial to focus on simple cooking methods using stewing and stir-frying.

As expected, having a low or middle/low level of cooking skills was significantly associated with having a low frequency of home cooking for both men and women. People with high levels of cooking skills may enjoy cooking and feel self-confident regarding their cooking, leading to a high frequency of home cooking [9, 42]. However, a significant association between a low level of cooking skills and high frequency of eating outside the home was found only among men. This result may reflect the gender difference in the prevalence of eating outside the home. The percentage of respondents who ate out at least once a week was 15.5% for women and 23.6% for men (Table 2). A previous nationally representative survey in Japan reported that this gender difference exists across all age groups in the country, suggesting that men tend to prefer eating outside the home [45]. The same national survey also reported that the percentage of people who consume packaged lunches or cooked meals is the same for both men and women [45]. Therefore, women may consume these meals rather than eating outside the home, even if they have a low level of cooking skills. Another possible reason for the gender difference in eating outside the home is that there is a fundamental difference in cooking ability between men and women. In other words, the men who were categorized as having a low level of cooking skills cannot prepare any kind of meal, but the women who were categorized as having a middle/low level of cooking skills may be able to make basic meals. In our study, 79% of the women categorized as having a middle/low level of cooking skills were originally in the middle-level cooking skills category (Table 1). Therefore, women may not have to rely on eating outside the home even if they have a middle/low level of cooking skills.

Unlike home cooking and eating outside the home, no dose–response relationship between cooking skills and low vegetable/fruit intake was observed among men. In a previous study using the original cooking skills scale in Switzerland, favorable associations between cooking skills and various food groups including vegetables and fruits were evident for women, but these associations were weak or nonexistent for men [9]. This gender difference may be explained by nutritional knowledge [22, 46]: Men may not have sufficient nutritional knowledge regarding healthy food choice, even if they have a high level of cooking skills. Additionally, men may be more likely to choose foods because of their sensory appeal rather than for health reasons [47]. Future work should investigate food skills, including meal planning, food safety, and nutrition knowledge [23].

A low level of cooking skills was associated with underweight but not with obesity. Although a low level of cooking skills was associated with a high frequency of eating outside the home among men, which is generally associated with obesity, the majority of older Japanese people participating in this study did not rely on eating outside the home. The percentage of people who ate out more than three times a week was only 5% for the study participants, compared with 35% for older Americans aged 60 years or older [29]. In our sample, more than 90% of the participants reported that their daily meals were mainly cooked by themselves or a family member (Table 1). Therefore, for older Japanese people, a low cooking frequency because of a low level of cooking skills may mean that they skip meals or eat simple meals or meals with poor nutritional value instead of eating outside the home. This would be more likely to lead to underweight than to obesity. A study examining the amount of rice served at local and chain restaurants in Japan found that most restaurants set the rice potion at an appropriate quantity for middle-aged and older people (> 160 g and < 200 g) [48]. Therefore, those eating outside the home in Japan may be unlikely to consume a high number of calories. When we additionally included frequency of home cooking and vegetable/fruit intake as potential mediators in our model, the ARRR of underweight decreased and became statistically non-significant among men, although it remained significant among men in charge of meals (Supplementary Table 3, Model 2). Another possible explanation for the association between cooking skills and underweight is that cooking skills may be a surrogate indicator of physical capacity in daily living. To examine this hypothesis, we included limitations in instrumental activities of daily living status [49, 50] in our model as a confounding factor, confirming that the ARRR of underweight remained significant (Supplementary Table 3, Model 3). Contrary to expectations, a low level of cooking skills was associated with underweight but not with obesity among older adults. For Asian people, underweight is a consistent risk factor for death, and this risk is higher than that associated with obesity [51]. Underweight has also been reported to be associated with frailty [52], fracture, and bone loss [53], which are critical obstacles to maintaining quality of life among older people [54, 55]. Therefore, it may be important for health policy makers to identify people with poor cooking skills and organize programs to enhance cooking skills to prevent underweight.

The association between cooking skills and underweight was especially prominent among men in charge

of meals, and this association remained significant in this group even after accounting for limitations in instrumental activities of daily living, frequency of home cooking, and vegetable/fruit intake (Supplementary Table 3, Model 4). This finding is plausible because many men have family members—often their wives—who prepare meals for them. Among the men in our study sample, 74% reported that a family member prepared their daily meals (Table 1). Considering that many men in charge of meals are widowed or divorced (Supplementary Table 2), these men may have difficulty preparing meals because they had few opportunities to prepare meals before losing their spouse. These men may thus be less motivated to cook and to eat, which can lead to a lower appetite [56]. Additionally, appetite decreases with age, and poor appetite has been shown to be related to, for example, lower intake of energy, protein, and vegetables/fruits; lower dietary diversity [57, 58]; and higher risks of malnutrition [59] and mortality [58]. Further studies are needed to examine the potential mechanisms of the risk of underweight caused by low levels of cooking skills for men. About half of older Japanese men who cook at home started cooking when they were over 50 years old [60]. Considering that cooking classes for men have increased over the past few decades in Japan, intervening at an older age may be feasible and acceptable.

This study had several limitations. First, we used self-reported weight and height to calculate BMI, which may have led to an under- or over-estimate of BMI [61]. A previous study demonstrated that, when calculated from self-reported weight and height, the BMI of older Japanese people was underestimated, compared with objective measures of weight and height; however, the same study showed that the BMI of underweight men and women was overestimated by 0.7 and 0.3, respectively, because these groups tended to over-report their weight [62]. Therefore, we may have underestimated the association of cooking skills with underweight. Second, we defined home cooking simply, excluding only the preparation of ready-to-eat food. Therefore, people who cooked low-quality meals or used some prepared foods in their cooking may have been included in the high frequency of home cooking category. This may have led to an underestimate of the association of cooking skills with low frequency of home cooking. Third, frequency of vegetable/fruit intake was assessed using a single, simple item. Future studies should use more detailed questions to assess which food groups are associated cooking skills. Fourth, we observed a ceiling effect for women's cooking skills, as has been reported in a previous study using the original cooking scale [9]. Considering the reduction in the available time for cooking in recent years, it may be beneficial to investigate cooking skills not only in terms of methods (e.g., boiling and stewing), but also in terms of the ability to prepare a variety of meals in a short time. Moreover, a thorough psychometric assessment of the modified cooking scale should be performed if it continues to be used. More comprehensive, validated measures for assessing food and cooking skill confidence are now available [63]. Therefore, it is possible to use these measurement methods in the future. Fifth, we could only evaluate a limited number of eating behaviors. Future work should examine associations between cooking skills and other aspects of diet, such as dietary pattern, food components, and portion size, to understand the mechanisms of the relationship between cooking skills and weight status. Sixth, because the municipalities that participated in the JAGES survey were not randomly selected, the generalizability of our findings to other populations in Japan is limited. Finally, because this study was cross-sectional, we could not assess causality: Reverse causation is possible, and unmeasured factors such as personality may confound the examined associations. For example, underweight may be accompanied by frailty or low muscle strength, which may make it difficult to cook some foods or to cook for a long time while standing, resulting in low confidence in one's cooking skills. However, more than half of the adult respondents in a previous study said that they had learned most of their cooking skills when they were teenagers and that they had learned these cooking skills mainly from their mothers [64]. Future randomized controlled trials comparing cooking, eating behaviors, and weight status among older adults with and without cooking skills interventions would clarify the causal association.

Conclusions

Using a large-scale cross-sectional study, we confirmed that women had higher levels of cooking skills than did men and that the associations of cooking skills with dietary behaviors and weight status differed by gender. Moreover, the associations of cooking skills with unhealthy dietary behaviors and weight status were especially pronounced among men who were in charge of meals. Considering the possibility that the person in charge of meals may change in older age, research on support to improve cooking skills among older people is needed.

Supplementary information

Supplementary information accompanies this paper at https://doi.org/10.1186/s12966-020-00986-9.

Additional file 1: Table S1. Adjusted relative risk ratios of underweight and overweight according to the cooking skills of older Japanese men (*n*=9,143) and women (*n*=10,595). **Table S2.** Characteristics of older Japanese men by cooking responsibility status (*n* = 9,203). **Table S3.**

Adjusted relative risk ratios of underweight by cooking skill among older Japanese men.

Abbreviations
CI: confidence interval; BMI: body mass index; JAGES: Japan Gerontological Evaluation Study

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Authors' contributions
YT conceived the design, analyzed the data, reviewed the literature, and wrote the first draft of the article. KK collected the data. TF revised the first draft. KK edited the manuscript. All authors approved the final version of the manuscript.

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Availability of data and materials
The datasets used and analyzed in the current study are from the JAGES study. All enquiries are to be addressed to the JAGES data management committee via e-mail: dataadmin.ml@jages.net. All JAGES datasets have ethical or legal restrictions for public deposition because of the inclusion of sensitive information from the human participants.

Ethics approval and consent to participate
The JAGES participants were informed that participation in the study was voluntary and that completing and returning the questionnaire via mail indicated their consent to participate in the study. The JAGES protocol was approved by the Ethics Committee in Research of Human Subjects at the National Center for Geriatrics and Gerontology (No. 992) and Chiba University Faculty of Medicine (No. 2493).

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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Does second‐hand smoke associate with tooth loss among older Japanese? JAGES cross‐sectional study

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Abstract

Objective

Second‐hand smoke (SHS) is considered a risk factor for a number of oral diseases. However, its influence on tooth loss, which is the final consequence of periodontal disease and caries, remains unknown. We aimed to evaluate the association between SHS experience and the number of remaining teeth among non‐smoking older Japanese individuals.

Methods

Cross‐sectional data from the Japan Gerontological Evaluation Study (JAGES) 2013 were used. From the 27,561 people ≥65 years of age who responded to a self‐reported questionnaire (response rate = 71.1%), data of 18,865 respondents who had never smoked were analysed. Multinomial logistic regression with multiple imputations was applied to estimate the odds ratio of the frequency of SHS exposures on the number of remaining teeth.

Results

The prevalence of participants with ≥20 teeth, 10–19 teeth, 5–9 teeth, 1–4 teeth, and no teeth were 53.2%, 20.4%, 9.9%, 6.6%, and 9.9%, respectively. The proportion of participants with SHS was 37.5%. After adjusting for sex, the SHS experience tended to be associated with a lower risk of having the fewer number of remaining teeth ($P < 0.05$). However, after being adjusted for age and sex, participants with SHS exposure at “a few times a week” and “almost every day” were significantly associated with the fewer number of teeth. After adding all other covariates, compared to the participants without any exposure to SHS, the odds ratio for having no teeth rather than having ≥20 teeth among the participants with daily exposure to SHS was 1.35 ($P < 0.01$).

Conclusion

Daily second‐hand smoke was significantly associated with fewer remaining teeth based on the self‐reported survey among older Japanese people.

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Association between childhood socioeconomic position and sports group participation among Japanese older adults: A cross-sectional study from the JAGES 2010 survey

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ABSTRACT

Sports group participation may have greater effects on health outcomes than exercising alone. Unhealthy lifestyles were reported to be specifically associated with lower socioeconomic positions (SEPs), and child poverty and the bipolarization of sports participation are currently major policy concerns in children. However, it remains unclear whether childhood SEP has any long-latency effect on sports group participation among older Japanese. Data were obtained from the Japan Gerontological Evaluation Study 2010 project, which used self-report questionnaires to survey individuals aged ≥65 years without disability from 27 municipalities (n = 23,320). According to their answers, respondents were assigned to one of three SEP groups: high, middle, or low. Poisson regression with robust variance and multiple imputations was used to examine the association between childhood SEP and sports group participation. After adjusting for health-related factors, low childhood SEP was negatively associated with sports group participation in men (prevalence ratio [PR] = 0.82, 95% confidence interval [CI] = 0.74–0.91) and women (PR = 0.88, 95% CI = 0.80–0.97). The PR was greatly attenuated after adjusting for educational attainment in both men (PR = 0.92, 95% CI = 0.83–1.02) and women (PR = 0.98, 95% CI = 0.89–1.08), and the significant association disappeared. Low childhood SEP is thus associated with lower sports group participation among older Japanese, though this may be attenuated by education. These findings suggest that it may be necessary to consider childhood SEP and the importance of education to increase sports group participation at an older age.

1. Introduction

Childhood socioeconomic position (SEP) are powerful predictors of health outcomes such as cardiovascular mortality, all-cause mortality (Cohen et al., 2010), and others (Galobardes et al., 2008; Rocha et al., 2019; Tamayo et al., 2010). Thus, since socioeconomic inequalities in childhood health have multiple adverse health consequences in later life, tackling these inequalities is an important public policy goal. Unhealthy lifestyles are reported to be correlated to a lower SEP (Foster et al., 2018). Several systematic reviews suggest that childhood SEP is an important determinant of later physical activity (PA) in adulthood (Elhakeem et al., 2015; Juneau et al., 2015). However, as there are fewer studies on older adults, it is not still completely understood whether childhood SEP contributes to later PA in old age.

The health benefits of PA for people of all ages are widely established (Lee et al., 2012; World Health Organization, 2018). In particular, sports group participation includes not only physiological benefits through increased PA but also psychological and social benefits through social participation beyond improvements attributed to individual types of PA (Eime et al., 2013; Farrance et al., 2016). A large

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cohort study of Japanese older adults showed that people who participated in sports groups showed a greater likelihood of avoiding functional disability than those who exercised alone (Kanamori et al., 2012), and that increasing the frequency of sports group participation alleviates worsening depressive symptoms compared with increasing daily walking time (Tsuji et al., 2017). In addition, another longitudinal study revealed that exercising with others has a more positive impact on mental well-being than exercising alone (Harada et al., 2019). Moreover, randomized controlled trials showed that social relations in exercise programs improved loneliness in older adults (Ehlers et al., 2017). This growing evidence suggests the possibility that sports group participation has a greater effect on health than PA alone, such as walking.

Understanding the association of childhood SEP with sports group participation among older adults may provide important insights into the pathways through which socioeconomic inequalities lead to lifelong adverse health consequences. It is particularly meaningful to examine this association among the Japanese people with a high relative child poverty rate (one in seven) (Ministry of Health, Labour and Welfare, 2018; OECD, 2019), along with the ongoing bipolarization of sports participation (Sasakawa Sports Foundation, 2015). However, most previous studies were based on American or European populations and have shown the association with PA, and no studies have examined whether childhood SEP later contributes to sports group participation among older Japanese adults. Therefore, this study aimed to examine the association between childhood SEP and sports group participation among Japanese older adults.

2. Methods

2.1. Study participants

This study utilized data from the Japan Gerontological Evaluation Study (JAGES) (Kondo and Rosenberg, 2018). The JAGES was established in 2010 to evaluate the social determinants of healthy aging among non-disabled people aged 65 or above, sampled from 31 municipalities in 12 of the 47 prefectures throughout Japan. From August 2010 to January 2012, a self-administered questionnaire was mailed to 169,215 community-dwelling individuals aged 65 or above who were physically and cognitively independent and living independently. Random sampling was used in the 16 large municipalities, while the questionnaire was sent to all eligible residents in the 15 small municipalities. Of the eligible participants, 112,123 returned the questionnaire (66.3% response rate) (Fig. 1). The JAGES questionnaire consisted of basic questions to be answered by all respondents, as well as five separate modules that were randomly allocated to participants (20% probability for each module). Of these, one data module, which included items related to childhood SEP (23,320 respondents; 10,657 men and 12,663 women), was used in this study. In this cross-sectional study, the analysis included 22,311 participants (10,276 men and 12,035 women) after excluding participants who reported limitations in activities of daily living (n = 1,009), defined as being unable to walk, take a bath, or use the toilet without assistance, and who were mistakenly included in the study (Fig. 1). The JAGES protocol was reviewed and approved by the Ethics Committee on Research of Human Subjects at Nihon Fukushi University (Approval No. 10–05). Written informed consent was assumed from the voluntary return of the questionnaire.

2.2. Participation in sports groups

This was assessed using the following question: "How often do you participate in a sports group or club?" Those who answered, "almost every day," "2 or 3 times a week," "once a week," "once or twice a month," "a few times a year," and "never." To examine the differences between people who have never been interested in sports group participation and those who have participated in sports groups, the participants were classified into two groups: "Non-participants (never)" and "Participants (other than never)," in accordance with a previous study (Ashida et al., 2016). Sports group participation included participation in not only team sports, but also sports organizations.

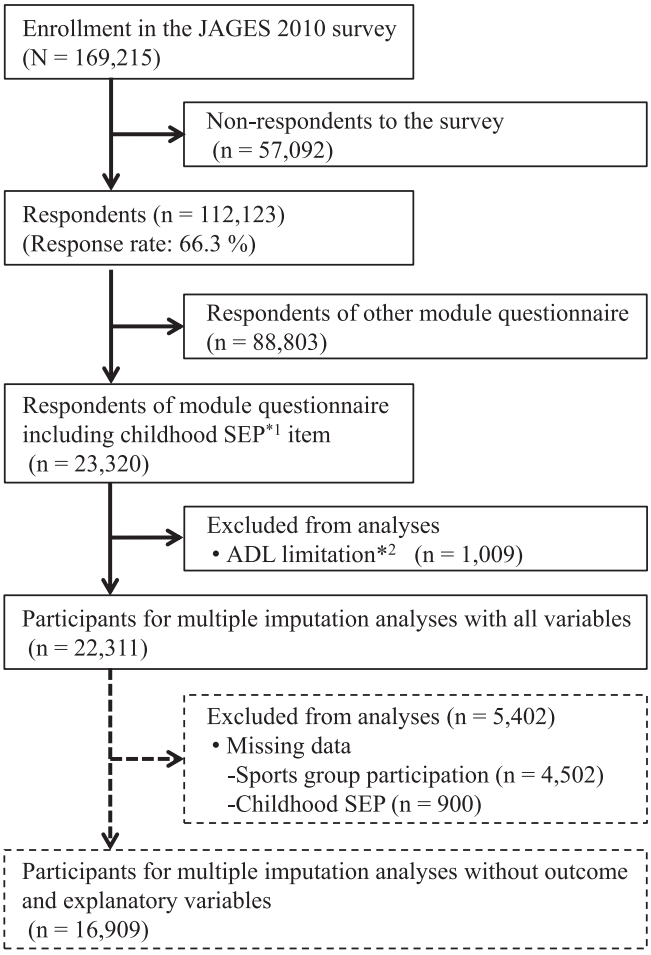

Fig. 1. Flow chart of participant selection in the Japan Gerontological Evaluation Study (JAGES) 2010 survey. *1 SEP: socioeconomic position. *2 ADL: activities of daily living.

2.3. Childhood SEP

This was retrospectively assessed by recalled subjective SEP using the following question: "How would you rate your socioeconomic status at the age of 15 years according to standards at that time?" Responses were arranged on a five-point Likert scale: "high," "middle-high," "middle," "middle-low," and "low." These responses were allocated to three categories: high (including "high" and "middle-high"), middle, and low (including "middle-low" and "low") to maximize the sample size for each category. This method has previously been validated using siblings' data (Ward, 2011). Moreover, recalled subjective SEP in childhood has shown a good correlation with adult height (as a proxy for childhood nutrition) and/or homeownership (Fujiwara et al., 2014; Tani et al., 2016; Yanagi et al., 2017).

2.4. Covariates

Based on previous studies (Kanamori et al., 2012; Tani et al., 2016; Yamakita et al., 2015; Yanagi et al., 2017), the following variables were used as covariates. As health-related factors, age (continuous variables), current medical treatment (yes/no), instrumental activities of daily

living (IADL), self-rated health, depression, body mass index (BMI), smoking status (non-smoker, ex-smoker, current smoker), alcohol intake (non-drinker, ex-drinker, or current drinker), marital status (married, widowed, divorced, single), providing emotional social support (yes/no), and receiving emotional social support (yes/no) were included. IADL was assessed using the Tokyo Metropolitan Institute of Gerontology Index of Competence ("good" [5 points] or "poor" [0–4 points]) (Koyano et al., 1991). Self-rated health is a subjective indicator that reflects the overall health status. In this study, we evaluated this indicator by asking the following question: "How is your current health status?" The possible responses were "excellent," "good," "fair," and "poor." Depression was measured using the short version of the Geriatric Depression Scale–15 (Japanese version) and was categorized into three groups ("no" [0–4 points], "mild" [5–9 points], "moderate to severe" [10–15 points]) (Nyunt et al., 2009; Schreiner et al., 2003). Body mass index (BMI) was calculated from self-reported height and weight (kg/m^2).

2.5. Mediators

According to a previous study, height (Fujiwara et al., 2014), educational attainment (Frenz et al., 2017; Galobardes et al., 2008; Lawlor et al., 2006), and adulthood SEP (Cheval et al., 2018; Umeda et al., 2015) were used as potential mediators. These variables were assessed from the self-reported questionnaire. Height was used as a proxy for the childhood nutritional environment and disease history (Silventoinen, 2003), and was categorized into five groups at 5 cm intervals for each sex, as shown in Tables 1-3. Previous studies confirmed a high correlation between self-reported and measured height among older people in Australia (Ng et al., 2011). Educational attainment was assessed categorized into three groups by years of schooling (< 10, 10–12, ≥13 years). As indicators of adulthood SEP, current annual household income, which reflects SEP in old-age, and longest-held occupation, which reflects SEP in middle-age, were included. Annual household income was calculated by dividing household income by the square root of the number of household members and categorized into three groups (< 2.00, 2.00–3.99, ≥4.00 million yen). Since previous studies have confirmed that the Japanese managerial/professional class appears to potentially experience a higher CHD risk compared to other occupations (Zaitsu et al., 2019), longest-held occupations were categorized into three groups: non-manual occupations (professional, technical, managerial work), manual occupations (clerical, sales/service, skilled/labor or agriculture/forestry/fishery worker, other), and no occupation (Tani et al., 2016).

2.6. Statistical analysis

Because sex has been shown to influence the relationship between childhood SEP and physical inactivity (Cheval et al., 2018)—and because, as noted by Hawkes et al. (2013), disaggregation by sex is essential in health research—sex was controlled by conducting stratified analysis.

To account for potential biases due to missing values, we conducted multiple imputation analyses with 22,311 study participants, who experienced no limitations in activities of daily living. Following Sterne et al. (2009), all variables included in the analysis, such as the outcome variables, explanatory variables, and covariates, were imputed. Table 1 and Supplementary Table 1 presents the number of participants for whom data was imputed (because of missing values). Under a missing-at-random assumption, we created 20 imputed data using a chained equation procedure (White et al., 2011). The estimated parameters were combined using Rubin's combination method (Rubin, 1987). Poisson regression with robust variance was used to examine the association between childhood SEP and sports group participation due to the relatively high prevalence of the latter (> 10%): in such cases, odds ratios obtained from logistic regression models can significantly overestimate prevalence ratios (Barros and Hirakata, 2003; McNutt et al., 2003).

Table 1
Characteristics of participants of the Japan Gerontological Evaluation Study (JAGES) 2010 survey (n = 22,311).

	Men (n = 10,276)		Women (n = 12,035)	
	n	(%)	n	(%)
Participation in sport group				
Participants	2,450	(23.8)	2,513	(20.9)
Almost every day	228	(2.2)	182	(1.5)
2 or 3 times a week	647	(6.3)	923	(7.7)
Once a week	497	(4.8)	811	(6.7)
Once or twice a month	474	(4.6)	347	(2.9)
A few times a year	604	(5.9)	250	(2.1)
Non-participants (Never)	6,084	(59.2)	6,762	(56.2)
Missing	1,742	(17.0)	2,760	(22.9)
Childhood SEP				
High (high or middle-high)	937	(9.1)	1,942	(16.1)
Middle	3,740	(36.4)	5,155	(42.8)
Low (middle-low or low)	5,057	(49.2)	4,173	(34.7)
Missing	542	(5.3)	765	(6.4)
Height*				
Tall	1,460	(14.2)	553	(4.6)
Middle-tall	2,687	(26.2)	2,051	(17.0)
Middle	3,292	(32.0)	3,986	(33.1)
Middle-short	1,745	(17.0)	3,394	(28.2)
Short	846	(8.2)	1,517	(12.6)
Missing	246	(2.4)	534	(4.4)
Educational level (years)				
≥13	2,250	(21.9)	1,472	(12.2)
10–12	3,365	(32.8)	4,324	(35.9)
< 10	4,481	(43.6)	5,883	(48.9)
Missing	180	(1.8)	356	(3.0)
Annual equivalized income (yen)				
≥4.00 million	1,064	(10.4)	1,005	(8.4)
2.00–3.99 million	3,630	(35.3)	3,401	(28.3)
< 2.00 million	4,272	(41.6)	4,820	(40.0)
Missing	1,310	(12.8)	2,809	(23.3)
Longest-held occupation				
Non-manual	3,367	(32.8)	1,099	(9.1)
Manual	5,905	(57.5)	7,473	(62.1)
None	54	(0.5)	1,061	(8.8)
Missing	950	(9.2)	2,402	(20.0)

SEP: socioeconomic position.
*Height in cm (men, women): tall (≥170, ≥160), middle-tall (165–169.9, 155–159.9), middle (160–164.9, 150–154.9), middle-short (155–159.9, 145–149.9), short (< 155, < 145).

Model 1 was first adjusted for health-related factors (age, current medical treatment, IADL, self-rated health, depression, BMI, smoking status, alcohol intake, marital status, providing or receiving emotional social support). Next, Model 2 added height as a childhood circumstance to investigate how much it changes the association. In addition, since several studies indicated that educational attainment resulted in attenuation of the associations between low childhood SEP and adverse health outcomes later in life (Frenz et al., 2017; Galobardes et al., 2008; Lawlor et al., 2006), educational attainment was further adjusted in Model 3 to examine whether it influences these associations. Additionally, adulthood SEP (annual equivalized income and longest-held occupations) was added to Model 3 to investigate the effect on participants of all SEP (Model 4).

For sensitivity analyses (as a complete case analysis), different multiple imputation analyses were performed for participants, which excluded the missing values for sports group participation (outcome) and childhood SEP (explanatory) variables (Supplementary Tables 2 and 3). In addition, sensitivity analyses with the cut-off setting of "once or twice a month" for sports group participation were performed (Supplementary Tables 4 and 5). All statistical analyses and multiple imputations were performed using Stata/SE version 15.1 (StataCorp

Table 2
Adjusted prevalence ratio with 95% CI for association of childhood SEP with participation in sports groups in older Japanese men in the Japan Gerontological Evaluation Study (JAGES) 2010 survey with all variable multiple imputations (n = 10,276).

	Model 1 PR (95% CI)	p	Model 2 PR (95% CI)	p	Model 3 PR (95% CI)	p	Model 4 PR (95% CI)	p
Childhood SEP								
High	Reference		Reference		Reference		Reference	
Middle	0.93 (0.84–1.02)	0.136	0.93 (0.84–1.03)	0.175	0.98 (0.89–1.09)	0.714	0.99 (0.89–1.09)	0.826
Low	0.82 (0.74–0.91)	< 0.001	0.83 (0.75–0.92)	< 0.001	0.92 (0.83–1.02)	0.120	0.93 (0.84–1.04)	0.191
Height								
Tall			Reference		Reference		Reference	
Middle-tall			1.00 (0.92–1.11)	0.849	1.03 (0.93–1.13)	0.596	1.04 (0.94–1.14)	0.469
Middle			0.93 (0.84–1.02)	0.127	0.96 (0.87–1.06)	0.390	0.98 (0.89–1.07)	0.620
Middle-short			0.90 (0.80–1.01)	0.076	0.95 (0.85–1.07)	0.428	0.98 (0.87–1.10)	0.689
Short			0.81 (0.69–0.95)	0.010	0.87 (0.75–1.02)	0.094	0.91 (0.77–1.06)	0.223
Education (years)								
≥13					Reference		Reference	
10–12					0.90 (0.83–0.97)	0.005	0.93 (0.86–1.01)	0.083
< 10					0.70 (0.64–0.76)	< 0.001	0.75 (0.69–0.82)	< 0.001
Annual equivalized income								
≥4.00 million yen							Reference	
2.00–3.99 million yen							0.94 (0.86–1.04)	0.225
< 2.00 million yen							0.86 (0.78–0.95)	0.003
Longest-held occupation								
Non-manual							Reference	
Manual							0.86 (0.80–0.92)	< 0.001
None							0.69 (0.36–1.33)	0.267

SEP: socioeconomic position; PR: prevalence ratio; CI: confidence interval.
Model 1: Adjusted for health-related factors (age, medication, instrumental activities of daily living, self-rated health, depression, body mass index, smoking status, alcohol intake, marital status, and social support).
Model 2: Model 1 + height.
Model 3: Model 2 + education.
Model 4: Model 3 + adulthood SEP (annual equivalized income, longest-held occupation).

Table 3
Adjusted prevalence ratio with 95% CI for association of childhood SEP with participation in sports groups in older Japanese women in the Japan Gerontological Evaluation Study (JAGES) 2010 survey with all variable multiple imputations (n = 12,035).

	Model 1 PR (95% CI)	p	Model 2 PR (95% CI)	p	Model 3 PR (95% CI)	p	Model 4 PR (95% CI)	p
Childhood SEP								
High	Reference		Reference		Reference		Reference	
Middle	0.98 (0.90–1.07)	0.668	0.99 (0.91–1.08)	0.785	1.04 (0.95–1.13)	0.433	1.03 (0.95–1.12)	0.485
Low	0.88 (0.80–0.97)	0.011	0.90 (0.82–0.99)	0.025	0.98 (0.89–1.08)	0.724	0.98 (0.89–1.08)	0.674
Height								
Tall			Reference		Reference		Reference	
Middle-tall			1.11 (0.95–1.29)	0.205	1.12 (0.96–1.31)	0.150	1.12 (0.96–1.31)	0.154
Middle			1.01 (0.87–1.18)	0.837	1.04 (0.89–1.21)	0.608	1.04 (0.89–1.21)	0.624
Middle-short			0.99 (0.85–1.16)	0.906	1.03 (0.88–1.20)	0.717	1.03 (0.88–1.21)	0.693
Short			0.85 (0.71–1.03)	0.091	0.90 (0.75–1.08)	0.242	0.90 (0.75–1.09)	0.280
Education (years)								
≥13					Reference		Reference	
10–12					0.91 (0.84–0.99)	0.032	0.92 (0.84–1.00)	0.057
< 10					0.74 (0.68–0.82)	< 0.001	0.77 (0.69–0.85)	< 0.001
Annual equivalized income								
≥4.00 million yen							Reference	
2.00–3.99 million yen							1.09 (0.97–1.22)	0.144
< 2.00 million yen							0.96 (0.86–1.07)	0.495
Longest-held occupation								
Non-manual							Reference	
Manual							0.95 (0.86–1.05)	0.307
None							0.91 (0.79–1.04)	0.169

SEP: socioeconomic position; PR: prevalence ratio; CI: confidence interval.
Model 1: Adjusted for health-related factors (age, medication, instrumental activities of daily living, self-rated health, depression, body mass index, smoking status, alcohol intake, marital status, and social support).
Model 2: Model 1 + height.
Model 3: Model 2 + education.
Model 4: Model 3 + adulthood SEP (annual equivalized income, longest-held occupation).

LLC, College Station, TX, USA) with statistical significance inferred at a two-tailed p-value of < 0.05.

3. Results

Among all participants including missing values, 22.2% were sports group participants (Table 1), and 49.2% of men and 34.7% of women reported low or middle-low SEP in childhood, while 9.1% of men and 16.1% of women reported high or middle-high childhood SEP. Among men, the percentages for 13 or more years' educational attainment and non-manual occupation were higher than among women.

The sociodemographic and health characteristics of the participants are shown in Supplemental Table 1. The mean age (standard deviation) was 73.9 (6.1) years (ranging from 65 to 101 years); 46.1% were men. Among men, being married was higher than among women. By contrast, compared to men, more women were non-smokers, non-drinkers, and had good IADL.

Table 2 shows the association between childhood SEP and the prevalence ratio (PR) of sports group participation in older men. Compared with the high childhood SEP group, the PR of sports group participation was 7% lower in the middle childhood SEP group and 18% lower in the low childhood SEP group in the health-related factors-adjusted model (Model 1). When analyses were controlled for height, the point estimates of PR for participation in sports groups were very slightly attenuated (Model 2). However, when analyses were controlled for educational attainment, the PR in the childhood SEP group was greatly attenuated (PR = 0.92, Model 3), and statistical significance disappeared. This association was very slightly attenuated in the low childhood SEP group after adjusting for adulthood SEP (Model 4).

When analyses were controlled for height, the point estimates of PR for participation in sports groups were slightly attenuated, although statistical significance remained the same (Model 2).

Among women, compared with the high childhood SEP group, the PR of sports group participation was 12% lower in the low childhood SEP group in the health-related factors-adjusted model (Model 1 in Table 3). When analyses were controlled for height, the point estimates of PR for participation in sports groups were slightly attenuated, although statistical significance remained the same (Model 2). However, when analyses were controlled for educational attainment, this association was no longer statistically significant (PR = 0.98, Model 3 in Table 3). The association was almost unchanged after adjusting for adulthood SEP (Model 4 in Table 3).

The sensitivity analysis that excluded the missing values for sports group participation and childhood SEP variables exhibited similar results with slightly smaller PRs (Supplemental Tables 2 and 3). The sensitivity analyses with the cut-off setting of "once or twice a month" revealed that the point estimates of PR exhibited similar results with a cut-off setting of "participants or non-participants" among men and women (Supplemental Tables 4 and 5).

4. Discussion

This study investigated the association between childhood SEP and sports group participation in older adults. Its results demonstrate that low childhood SEP is associated with lower sports group participation in older men, even after adjusting for health-related factors. After adjustment for educational attainment, the PR in the low childhood SEP group was both greatly attenuated and more attenuated than when adjusted for any other health-related or social characteristic in adulthood. This suggests that education may possibly shrink differences in the association between childhood SEP and sports group participation among older adults.

Despite inconsistencies in the results, prior evidence suggests that low childhood SEP groups participate less frequently in leisure-time PA in adulthood and early old age compared with high childhood SEP groups (Elhakeem et al., 2015, 2017). Consistent with these studies, our study of older adults found that lower childhood SEP groups were less likely to participate in sports groups. While both men and women showed similar results, PR was consistently lower for men than women. One possible explanation is a sex difference in the tracking of PA from childhood to adulthood. Several previous studies have reported that men show greater stability in tracking PA compared to women in all phases of the life course (Telama et al., 2014). This difference is supported by findings that many life events, such as pregnancy, getting married, or having small children, have a greater influence on the PA of women than on that of men (Allender et al., 2008; Engberg et al., 2012; Telama et al., 2014). In addition, it has been suggested that men are more likely to participate in PA than women in childhood (World Health Organization, 2018), and also that men from lower SEP groups are more likely than women to engage in risky health behaviors, such as smoking, an unhealthy diet, and physical inactivity (Lawlor et al., 2006), which may be further explanations for the sex difference.

Our findings demonstrate that educational attainment has a stronger effect than other factors in attenuating the association of low childhood SEP with lower sports group participation in older adults. Our findings showed that the PR for participation in sports groups remained almost unchanged after adjusting for height, a variable often utilized as a proxy for childhood nutrition. In contrast, after adjusting for educational attainment, the PR in the low childhood SEP group was greatly attenuated. This is consistent with many previous studies (Elhakeem et al., 2015; Gidlow et al., 2006). Education is completed early in the life course and associated with subsequent income, employment, social networks, and behaviors (Byhoff et al., 2017). Moreover, educational attainment is associated with numerous mental and physical health outcomes (Byhoff et al., 2017; Kubota et al., 2017; Ladin, 2008; Xu et al., 2016). Furthermore, those who achieve higher educational attainment might have pursued a healthy lifestyle regardless of their personal income changes (Montez and Friedman, 2015). Our findings support the importance of education in explaining the link between childhood SEP and PA in adulthood (Elhakeem et al., 2015), and show that education also explains the link between childhood SEP and sports group participation in older adults. In the model, after adjusting for adulthood SEP, the PR remained almost unchanged. This suggest that education more strongly mediates the association between childhood SEP and sports group participation in adulthood than adulthood SEP. Thus, although education mediates the association between childhood SEP later-life sports participation, further study is called for to examine the indirect effects mediating educational attainment.

The mechanisms that explain the association between childhood SEP and later-life sports participation are not fully understood. However, given the similarity of the association between childhood SEP and PA (Elhakeem et al., 2015), educational attainment that increases health literacy may be one possible pathway (Montez and Friedman, 2015). Lower childhood SEP tends to restrict future SEP (Byhoff et al., 2017), as mentioned above. Another pathway may be the tracking of PA. Numerous studies consistently show that children from families with low SEP participate less in sports groups compared to high- SEP children (Stalsberg & Pedersen, 2010), and participation in PA and sports in childhood tends to be maintained throughout adulthood (Cleland et al., 2012; Telama et al., 2014) and thus old age. For these reasons, intervention to enhance educational attainment and promote sports in childhood may be an effective investment to increase sports group participation in future older adults. These childhood investments may lead to extending healthy life expectancy in the future. Additional studies conducting a mediation analysis are needed in order to demonstrate these associations and clarify the mechanism driving childhood SEP and sports group participation later in life.

4.1. Strengths and lsimitations

This study's strengths include the large sample, comprising older

adults from across Japan, and the inclusion of a wide range of variables. To our knowledge, no prior study has investigated the association between childhood SEP and sports group participation in older adults. Our findings establish childhood SEP as a new factor associated with sports group participation among Japanese older adults.

However, several limitations of this study should be considered. First, childhood SEP was evaluated retrospectively due to the cross-sectional design and self-reported method and is therefore susceptible to recall bias and could not establish causality. However, previous studies have confirmed the validity of retrospectively evaluating subjective childhood SEP (Ward, 2011) and childhood neighborhood context (Osypuk et al., 2015). In addition, the childhood subjective SEP was found to correlate with other objective indicators, of deprivation, such as height and SEP achieved in adulthood (Sakurai et al., 2010). Further studies are needed to examine whether there is a similar association between objective childhood SEP and participation in sports groups in old age. Second, since all measures were self-reported and the health status of some items such as smoking status and alcohol intake did not have detailed information, it is possible that measurement error occurred. Third, for the sampling method, while randomization was used in urban areas, the questionnaire was given to all eligible residents in the rural areas due to the small number of residents. Fourth, the generalizability of the results requires attention since this study did not include older adults with long-term-care insurance. Finally, information on participation in PA and in sports groups, including intensity, frequency, and types, was lacking. It would be useful to understand the mechanisms whereby childhood SEP affects sports group participation in old age. Therefore, further robust studies, including participation in PA and sports group participation at the early life stage, are needed to clarify this association.

5. Conclusion

This study demonstrated that low childhood SEP is associated with lower participation in sports groups among older adults, although this association may be attenuated by education. Our study highlighted the importance of education and implementing policies to tackle child poverty in order to increase sports group participation across the life course.

CRediT authorship contribution statement

Mitsuya Yamakita: Conceptualization, Methodology, Formal analysis, Writing - original draft. **Satoru Kanamori:** Methodology, Investigation, Writing - review & editing. **Naoki Kondo:** Data curation, Formal analysis, Writing - review & editing, Supervision, Funding acquisition, Project administration. **Toyo Ashida:** Methodology, Writing - review & editing. **Takeo Fujiwara:** Investigation, Methodology, Writing - review & editing, Supervision. **Taishi Tsuji:** Data curation, Methodology, Formal analysis. **Katsunori Kondo:** Conceptualization, Methodology, Investigation, Writing - review & editing, Supervision, Funding acquisition, Project administration.

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Availability of data and materials

Data are from the JAGES project. All inquiries should be addressed to the data management committee via e-mail: dataadmin.ml@jages.net. All JAGES datasets have ethical or legal restrictions for public deposition due to the inclusion of sensitive information from human participants.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2020.101065.

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Eating Behaviors
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Adverse childhood experiences and fruit and vegetable intake among older adults in Japan

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Highlights

•Adverse childhood experiences (ACEs) may affect health behaviors in adulthood.
•We tested if ACEs were linked with fruit and vegetable intake (FVI) in late adulthood.
•Those with multiple ACEs had higher prevalence of low FVI.
•This association was more pronounced among females.

Abstract

Background

Although adverse childhood experiences (ACEs) have been linked to negative health behaviors in adulthood, few studies have investigated if the impact continues until late

adulthood. We examined the association between ACEs and fruit and vegetable intake (FVI) among older adults in Japan.

Methods

Data came from the Japan Gerontological Evaluation Study (JAGES), 2013 in which 24,271 individuals aged ≥65 years participated. The number of ACEs was calculated (0, 1 and ≥2) while low FVI was defined as consuming fruit and vegetables less than once a day. A sex-stratified multilevel Poisson regression analysis was used to investigate the association between ACEs and low FVI.

Results

Among men, 35.4% reported at least one ACE while the corresponding figure for women was 30.6%. Compared to those without ACEs, the prevalence ratios for low FVI among those who reported ≥2 ACEs were 1.51 (95% confidence interval [CI] = 1.30–1.75) for women and 1.28 (95% CI = 1.14–1.44) for men after adjusting for age and childhood economic hardship. Although these associations were attenuated after adjusting for socio-demographic and health-related variables, the link between ACEs and low FVI remained statistically significant among women. Of the seven individual forms of ACE, psychological neglect was significantly associated with low FVI (PR = 1.16, 95% CI = 1.03–1.31) among women in the final model.

Conclusions

ACEs are associated with low FVI among older Japanese adults. Our results suggest that the detrimental effect of ACEs on health behavior may stretch across the life course.

Keywords

Adverse childhood experience; Fruit and vegetable intake; Older people; Life course

Geriatrics Gerontology INTERNATIONAL

ORIGINAL ARTICLE: EPIDEMIOLOGY, CLINICAL PRACTICE AND HEALTH

Accuracy of self‐reported weight, height and body mass index among older people in Japan

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Abstract

Aim

Weight and height are usually self‐reported in population‐based epidemiological surveys. While the accuracy of self‐reports has been extensively studied in younger populations, less is known in older populations. We investigated the accuracy of self‐reported weight, height and body mass (BMI) in an older cohort in Japan, where overweight/obesity and underweight coexist.

Methods

We used data from older Japanese adults (≥65 years) participating in the Japan Gerontological Evaluation Study in 2016 to 2017 (7357 men and 9271 women). Self‐report data were linked to objective data obtained from clinical examinations.

Results

The mean ± standard deviation (SD) age was 74.5 ± 5.8 years, mean ± SD weight, height and BMI were 55.7 ± 10.1 kg, 156.0 ± 8.9 cm and 22.8 ± 3.1, respectively. Results showed high intraclass correlation coefficients for self‐reported and measured values (0.97 for weight; 0.96 for height). While weight/height were overestimated among men (weight by 0.096 kg; height by 0.27 cm) and women (weight by 0.18 kg; height by 0.27 cm), BMI tended to be slightly underestimated (−0.034 kg/m^2 for men; −0.037 kg/m^2 for women). However, the absolute differences between self‐reported and measured values were not negligible; people had a higher risk for both under‐ and overestimation of their BMI category with increasing age. Lower education predicted BMI overestimation, whereas lower income predicted BMI underestimation.

Conclusions

Overall accuracy of self‐reported body habitus was higher in this cohort of older Japanese compared with previous reports. Nevertheless, misclassification of BMI due to the misreporting of their weight/height was more common among the oldest‐old, as well as those with lower education and income. **Geriatr Gerontol Int 2020; 20: 803–810**.

Geriatrics & Gerontology INTERNATIONAL

ORIGINAL ARTICLE: EPIDEMIOLOGY, CLINICAL PRACTICE AND HEALTH

Association between visual status and social participation *in older Japanese:* The JAGES cross-sectional study

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Highlights

·There is an association between visual status and social participation.
·People with better vision are more likely to participate in a wide range of social organizations.
·Participation in senior citizen clubs was not associated with visual status.
·Excellent/very good vision was associated with increased volunteerism.
·Poor vision disrupted participation in activities that require physical activity.

Abstract

Rationale

Population aging in Japan has been accompanied by increases in those with visual impairment. No previous study has examined whether visual impairment is associated with reduced social participation in older people in Japan.

Methods

In this cross-sectional study, questionnaires were mailed to older people living in 39 Japanese communities in 2016. Data from 24,313 respondents (70.3%, 74.0 ± 6.2 years) included information on visual status, social participation, socioeconomic status, and health. Visual status was measured by self-report (excellent, very good, good, or fair/poor).

Results

The prevalence of visual impairment (fair/poor) was 9.3%. After adjusting for individual covariates in multinominal logistic regression analysis with multiple imputations, visual status was significantly associated with reduced participation (once a week or more) in volunteer groups, sports groups, hobby groups, neighborhood associations, study/cultural groups, health promotion groups, and involvement in teaching skills/passing on experiences to others (p for trend <0.01). On the other hand, participation in senior citizen clubs was not associated with visual status (p for trend = 0.07). While excellent/very good vision was associated with increased volunteerism (e.g., involvement in teaching skills/passing on experiences to others: Odds ratios (OR) 1.78/1.21), poor vision disrupted participation in activities that require physical activity (e.g., sports groups: OR 0.64).

Conclusion

These results suggest that vision status is an important determinant of social participation among older adults in Japan.

Keywords

Japan; Social participation; Visual status; Visual impairment; Older adults; Social capital

原　著

ウォーキングによる健康ポイント事業が高齢者の歩行時間，運動機能，うつに及ぼす効果：傾向スコアを用いた逆確率重み付け法による検証

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目的　本研究は，歩行量に応じてポイントを得るウォーキングポイント事業による参加高齢者の歩行時間の増加，運動機能の低下予防とうつの抑制効果について傾向スコアによる逆確率重み付けを用いて検証することを目的とした。

方法　日本老年学的評価研究（JAGES）が横浜市在住の要介護認定を受けていない65歳以上を対象に実施した，2013年と2016年の2時点の調査データを用いた。横浜市が2014年度に開始した「よこはまウォーキングポイント事業（YWP）」への参加状況を2016年調査で尋ねた。性，年齢，1日の平均歩行時間（～30分未満，30～59分，60～89分，90分～），運動機能（基本チェックリスト5項目の該当数），うつ（Geriatric Depression Scale 日本語15項目版），YWPの参加状況の回答に欠損があった者を除外した4,509人を分析対象者とした。分析は，YWP参加群に対する歩行時間，運動機能，うつの効果について，傾向スコアによる逆確率重み付けを用いて検証した。

結果　対象者のうちYWP参加群は，758人（16.8％）であった。傾向スコアによる逆確率による重み付けでYWP参加群と非参加群の背景要因のバランスを取った結果，参加群は非参加群に比べて，歩行時間は有意に増加し（非標準化偏回帰係数［B］＝3.61，95％信頼区間［95％ CI］：1.04，6.17），運動機能得点（B＝－0.13，95％ CI：－0.23，－0.03）およびうつ得点は有意に減少した（B＝－0.21，95％ CI：－0.42，－0.01）。

結論　ウォーキングポイント事業は，高齢者の歩行時間の増加や運動機能の低下予防，うつの抑制に効果があることが示唆された。自治体による歩行量に応じた健康ポイント事業は，対象者を選別しないポピュレーションアプローチとして参加する高齢者の健康増進に役立つ取組だと考えられる。

Key words：高齢者，インセンティブ，ウォーキング，傾向スコア

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Ⅰ　緒　　言

健康日本21（第二次）[1]では，「健康寿命の延伸と健康格差の縮小」を基本的方向として定めている。厚生労働省は，健康づくりに関心が低い「健康無関心層」も含めた健康づくりを目指すポピュレーションアプローチの一つとして様々なインセンティブの提供を挙げている[2]。近年，自治体や健康保険組合などでは，インセンティブの付与による健康ポイント事業が導入され，健康長寿社会の構築に向けた取組として期待されている。

インセンティブの付与による健康づくりは，身体活動の促進や健康に対する行動変容に効果的であることが海外の先行研究で報告されている[3~5]。Finkelstein et al.[5]は，50歳以上の中年・高齢者を対象にインセンティブの付与によるウォーキングを含む運動プログラムの介入研究を実施し，対照群と比較して介入群では歩行時間が増加したことを報告している。我が国では，40歳以上の中年・高齢者を対象にした複数自治体連携型大規模健幸ポイントプロジェクト[6]において，全対象者の歩行量が増加した

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ことが報告されているが，インセンティブの付与による身体活動量への効果を検証した研究は，報告書[6]や会議録[7]に留まっており，うつへの効果や高齢者を対象にした研究はない。

ウォーキングは，高齢者において最も一般的な活動で，経済的費用が少なく，日常生活に取り入れやすい活動である[8,9]。日本の高齢者においてもグループで行う運動の種類として男女とも2番目に多い種目は，ウォーキングである[10]。また，日本における1年間に行われた運動・スポーツの種目では，ウォーキングが62.1％と最も高く，年代別では70代の割合が最も高いことが報告されている[11]。高齢者を対象としたウォーキングを含む運動プログラムによる介入研究では，歩行量の増加[12〜14]，運動機能の向上[13〜18]，精神的健康[14,19]や認知機能[12]が改善したことが報告されている。日本の地域在住高齢者を対象にした横断研究では，ウォーキングをしている高齢者は，うつが少なく，とくに女性では主観的健康感が高いことが報告されている[10]。

しかしながら，我が国において，全市的なデータにより，自治体が実施するウォーキングによる健康ポイント事業（以下，ウォーキングポイント）という緩やかな介入が高齢者の歩行時間，運動機能，うつに及ぼす効果について対照群を設定し，交絡を調整して検証した研究は見当たらない。近年，観察研究において交絡を調整する統計手法として傾向スコア法[20]が利用される機会が増えている。これは，2つの群間の差異を調整しバランスを取って擬似ランダム化した比較ができる利点がある[21,22]。傾向スコア法の中でも逆確率重み付け（the inverse probability of treatment weighting：IPTW）は，全対象を分析に含めることができる点で，バイアスがより小さい方法であると考えられる[23]。そこで，本研究は，横浜市在住高齢者を対象に，IPTWを用いてウォーキングポイントが歩行時間の増加，運動機能の低下予防とうつの抑制に効果があるかを検証することを目的とする。

Ⅱ　研究方法

1.　対象

横浜市は，市内在住および在勤の18歳以上を対象とする健康づくり事業として，2014年度より「よこはまウォーキングポイント事業（以下，YWP）」を実施している。YWPの募集は，自治体のホームページ，自治体記者発表，広報誌とメディアへの掲載や各種イベントなどで周知が行われた。申込は，ホームページ，市役所，区役所，地域ケアプラザ，スポーツセンターで配布されている申込書に本人が記載し，申込書と本人確認書類を自治体に郵送して行われた。YWP参加者には，自治体より無料で歩数計が配布された。YWP参加者へのインセンティブは，歩数に応じたポイントが付与され，抽選でポイント数に応じた景品が提供された。ポイント数の確認は，歩数計を横浜市内の商業施設や公共施設などに設置されている専用端末にのせて歩数データを送信し，YWPホームページにログイン後，本人のサイトで確認できた。

事業評価のためのデータとして，日本老年学的評価研究（Japan Gerontological Evaluation Study：以下，JAGES）[24]が横浜市在住の要介護認定を受けていない65歳以上を対象に2013年と2016年に実施した調査データを個人レベルで結合した2時点の縦断データを用いた。調査対象者の選定方法については，回収率6割を想定した上で1地域ケアプラザ圏域（およそ中学校区に相当）ごとに約50人の調査票（性と前期・後期高齢者がおよそ均等）の回収を目標とし，地域ケアプラザ圏域単位で性と年齢を層化した無作為抽出を行った。2013年調査では136地域ケアプラザの12,010人に調査票を郵送し，7,312人から回答が得られた（回収率：60.9％）。2016年調査では，2013年調査で回答が得られたうち，要介護認定を受けた者や転居した者を除く6,575人に調査票を配布し，5,111人から回答が得られた（回収率：77.7％）。本研究ではこのうち，性，年齢，歩行時間，運動機能，うつ，YWPの参加状況に関する項目に対して回答に欠損があった者を除外した4,509人を分析対象者とした。

本研究は，横浜市との「介護保険の政策評価及び社会疫学研究に関する共同研究」および，データ結合，分析，結果報告・公表に関して「横浜市と国立長寿医療研究センター及び日本老年学的評価研究機構との介護保険制度等の政策評価及び社会疫学研究に関する研究協定」における個人情報保護特記事項に基づいて実施した。なお本研究は，一般社団法人日本老年学的評価研究機構の倫理審査委員会の承認を受け（承認番号：2019-03，承認年月日：2020年2月15日），実施した。

2.　分析項目

1）　従属変数

本研究のアウトカムとして，1日の平均歩行時間，運動機能，うつの3指標を用いた。

歩行時間は，「平均すると1日の合計で何分くらい歩きますか」と尋ね，「30分未満」，「30〜59分」，「60〜89分」，「90分以上」の4件法の選択肢に対して，それぞれ15分，45分，75分，105分に換算し連続量として分析した。従属変数では，2013年から

2016年の歩行時間の変化量とし，正の場合は，歩行時間が増加したことを示す。

運動機能は，「基本チェックリスト」(厚生労働省)の「運動器の機能向上」[25]に関する5項目（No.6〜10）のうち「階段を手すりや壁をつたわらずに昇っていますか」，「椅子に座った状態から何もつかまらずに立ち上がっていますか」，「15分位続けて歩いていますか」の各項目について「はい」を0点，「いいえ」を1点，「この1年間に転んだことがありますか」，「転倒に対する不安は大きいですか」の各項目について「はい」を1点，「いいえ」を0点とし，合計得点（最小0点−最大5点）を用いた。合計得点が高いほど，運動機能が低下していることを示す。従属変数では，2013年から2016年の運動機能合計得点の変化量とし，負の場合は，運動機能が改善したことを示す。

うつは，老年期うつ評価尺度（Geriatric Depression Scale：以下，GDS）[26]の日本語15項目版を用いた。本尺度は，最小0点−最大15点で評価され，得点が高いほどうつが悪化していることを示す。従属変数では，2013年から2016年のGDS合計得点の変化量を算出し，負の場合は，うつが改善したことを示す。

2)　独立変数

YWPの参加状況は，2016年の調査票の「「よこはまウォーキングポイント事業」に参加していますか」という設問に対し，「参加している」を参加群，「参加してないが，参加してみたい」，「参加したくない」および「参加できない（入院中や体調不良などのため)」を非参加群とした。

3)　調整変数

調整変数は，いずれも2013年調査の変数を用いた。基本属性として性，年齢（65−69歳，70−74歳，75−79歳，80−84歳，85歳以上），社会経済状況として同居状況（一人暮らし，家族などと同居（二世帯住宅を含む），その他（施設入居など)），教育年数（13年未満，13年以上），等価所得（200万円未満，200−400万円未満，400万円以上/年），就労（就労している，退職して現在就労していない，職に就いたことがない）を用いた。健康状態および健康行動として，治療疾患の有無，主観的健康感，body mass index（以下，BMI）（18.5 kg/m^{2}未満，18.5−25 kg/m^{2}未満，25 kg/m^{2}以上），飲酒状況，喫煙状況，社会参加，活動能力（老研式活動能力指標[27]の合計得点のうち13点を満点，12点以下を非満点）を用いた。

主観的健康感は，「とてもよい」，「まあよい」を「よい」，「あまりよくない」，「よくない」を「よくない」とした。社会参加は，「ボランティアのグループ」，「スポーツ関係のグループやクラブ」，「趣味関係の会のグループ」，「学習・教養サークル」，「特技や経験を他者に伝える活動」の5項目のいずれかに週1回以上参加した者を「あり」，参加してない者を「なし」とした。いずれの変数もダミー変数として使用し，不明（無回答）であることも分析に投入した。

3.　分析方法

まず，YWP参加別に，歩行時間，運動機能，うつの2013年調査の時間・点数と変化量の平均値と標準偏差，および各調整変数の人数分布と割合を算出した。従属変数と調整変数のYWP参加別による比較について，量的変数の平均値の比較はt検定を，質的変数はカイ二乗検定を用いた。次に，YWP参加群に対する歩行時間，運動機能，うつの効果について，IPTWを用いて検証した。対象者の傾向スコアの推定値は，YWP参加の有無を従属変数，調整変数を独立変数としたロジスティック回帰分析により求めた。調整変数のバランスを確認するために，標準化差を使用した。標準化差は，独立変数の群間のバランスの程度を表す指標で，0.1未満であればバランスが取れていると判断した[28]。信頼区間の計算にはロバスト分散を用いた。また，感度分析として，従属変数を歩行時間，運動機能，うつの変化量とし，YWP参加の有無を独立変数，性，年齢，同居状況，教育年数，等価所得，就労，治療疾患の有無，主観的健康感，BMI，飲酒状況，喫煙状況，社会参加，活動能力を調整変数とした重回帰分析を行った。さらに，YWPの参加状況において，「参加できない（入院中や体調不良などのため)」を分析対象から除外してIPTWを行った。統計解析の有意水準は5%とし，STATA MP16.0（Stata Corp LP，College Station, Texas, USA）を使用した。

Ⅲ　研究結果

1.　対象者の属性

表1に対象者の2013年調査における属性の特徴を示した。参加群は，758人（16.8%）であった。歩行時間の変化量の平均値（標準偏差）は，参加群で0.7（28.2）分増加しているのに対して，非参加群では3.3（28.0）分減少した。運動機能の変化量の平均値（標準偏差）は，両群ともに点数が増加した（それぞれ，0.2（1.0）点；0.3（1.2）点)。うつの変化量の平均値（標準偏差）は，両群ともに点数が減少した（それぞれ，−0.1（2.0）点；−0.04（2.3）点)。また，参加群は，非参加群と比較して年齢が低く，一人暮らしや就労が少なく，社会参加が多い

表1　対象者の概要

		全 体（n＝4,509）	よこはまウォーキングポイント事業（YWP）		P
			参加群（n＝758）	非参加群（n＝3,751）	
		平均値/人数（標準偏差/%）	平均値/人数（標準偏差/%）	平均値/人数（標準偏差/%）	
歩行時間（分/日）	2013年調査	57.9(29.3)	63.2(27.7)	56.9(29.5)	＜0.001[e]
	変化量	−2.6(28.0)	0.7(28.2)	−3.3(28.0)	＜0.001[e]
運動機能[a]（点）	2013年調査	1.1(1.1)	0.9(1.0)	1.1(1.1)	＜0.001[e]
	変化量	0.3(1.2)	0.2(1.0)	0.3(1.2)	0.002[e]
うつ[b]（点）	2013年調査	2.9(3.0)	2.1(2.49)	3.0(3.1)	＜0.001[e]
	変化量	−0.1(2.2)	−0.1(2.0)	−0.04(2.3)	0.530[e]
性	男性	2,196(48.7)	357(47.1)	1,839(49.0)	0.330[f]
	女性	2,313(51.3)	401(52.9)	1,912(51.0)	
年齢	65–69歳	1,418(31.4)	265(35.0)	1,153(30.7)	＜0.001[f]
	70–74歳	1,488(33.0)	281(37.1)	1,207(32.2)	
	75–79歳	990(22.0)	159(21.0)	831(22.2)	
	80–84歳	462(10.2)	44(5.8)	418(11.1)	
	85歳以上	151(3.3)	9(1.2)	142(3.8)	
同居状況	一人暮らし	585(13.0)	76(10.0)	509(13.6)	0.001[f]
	家族などと同居（二世帯住宅を含む）	3,758(83.3)	665(87.7)	3,093(82.5)	
	その他（施設入居など）	47(1.0)	8(1.1)	39(1.0)	
	無回答	119(2.6)	9(1.2)	110(2.9)	
教育年数	13年未満	2,708(60.1)	414(54.6)	2,294(61.2)	0.002[f]
	13年以上	1,728(38.3)	334(44.1)	1,394(37.2)	
	無回答（その他を含む）	73(1.6)	10(1.3)	63(1.7)	
等価所得	200万円未満	1,470(32.6)	226(29.8)	1,244(33.2)	0.018[f]
	200–400万円未満	1,866(41.4)	353(46.6)	1,513(40.3)	
	400万円以上	648(14.4)	98(12.9)	550(14.7)	
	無回答	525(11.6)	81(10.7)	444(11.8)	
就労	就労している	1,003(22.2)	140(18.5)	863(23.0)	＜0.001[f]
	退職して現在就労していない	2,845(63.1)	530(69.9)	2,315(61.7)	
	職に就いたことがない	438(9.7)	56(7.4)	382(10.2)	
	無回答	223(4.9)	32(4.2)	191(5.1)	
治療疾患の有無	あり	3,396(75.3)	564(74.4)	2,832(75.5)	0.720[f]
	なし	845(18.7)	150(19.8)	695(18.5)	
	無回答	268(5.9)	44(5.8)	224(6.0)	
主観的健康感	よくない	537(11.9)	48(6.3)	489(13.0)	＜0.001[f]
	よい	3,845(85.3)	686(90.5)	3,159(84.2)	
	無回答	127(2.8)	24(3.2)	103(2.7)	
BMI[c]	18.5 kg/m^2 未満	344(7.6)	47(6.2)	297(7.9)	0.210[f]
	18.5–25 kg/m^2 未満	3,231(71.7)	565(74.5)	2,666(71.1)	
	25 kg/m^2 以上	820(18.2)	127(16.8)	693(18.5)	
	無回答	114(2.5)	19(2.5)	95(2.5)	
飲酒状況	飲む	1,974(43.8)	360(47.5)	1,614(43.0)	0.058[f]
	飲まない	2,522(55.9)	397(52.4)	2,125(56.7)	
	無回答	13(0.3)	1(0.1)	12(0.3)	
喫煙状況	吸う	429(9.5)	31(4.1)	398(10.6)	＜0.001[f]
	吸わない	4,061(90.1)	726(95.8)	3,335(88.9)	
	無回答	19(0.4)	1(0.1)	18(0.5)	
社会参加	なし	2,354(52.2)	297(39.2)	2,057(54.8)	＜0.001[f]
（週1回以上）	あり	1,703(37.8)	412(54.4)	1,291(34.4)	
	無回答	452(10.0)	49(6.5)	403(10.7)	
活動能力[d]	非満点	2,546(56.5)	359(47.4)	2,187(58.3)	＜0.001[f]
	満点	1,810(40.1)	388(51.2)	1,422(37.9)	
	無回答	153(3.4)	11(1.5)	142(3.8)	

a)「基本チェックリスト」の「運動器の機能向上」に関する5項目（No. 6〜10）の合計得点に基づく。
b) Geriatric Depression Scale 日本語15項目版による。
c) body mass index
d) 老研式活動能力指標の合計に基づく。
e) t 検定
f) カイ二乗検定

表 2　IPTW[a)]による調整前と調整後の対象者の概要

		IPTW[a)]による調整前			IPTW[a)]による調整後		
		平均値		標準化差	平均値		標準化差
		参加群	非参加群		参加群	非参加群	
性	男性	0.47	0.49	−0.039	0.49	0.49	−0.003
	女性	0.53	0.51	0.039	0.51	0.51	0.003
年齢	65–69歳	0.35	0.31	0.090	0.32	0.31	0.011
	70–74歳	0.37	0.32	0.103	0.33	0.33	−0.003
	75–79歳	0.21	0.22	−0.029	0.22	0.22	−0.006
	80–84歳	0.06	0.11	−0.193	0.10	0.10	0.005
	85歳以上	0.01	0.04	−0.167	0.03	0.03	−0.015
同居状況	一人暮らし	0.10	0.14	−0.110	0.14	0.13	0.023
	家族などと同居（二世帯住宅を含む）	0.88	0.82	0.148	0.83	0.83	−0.009
	その他（施設入居など）	0.01	0.01	0.002	0.01	0.01	0.003
	無回答	0.01	0.03	−0.123	0.02	0.03	−0.032
教育年数	13年未満	0.55	0.61	−0.133	0.59	0.60	−0.011
	13年以上	0.44	0.37	0.141	0.39	0.38	0.010
	無回答（その他を含む）	0.01	0.02	−0.030	0.02	0.02	0.004
等価所得	200万円未満	0.30	0.33	−0.072	0.33	0.33	0.017
	200–400万円未満	0.47	0.40	0.126	0.40	0.41	−0.034
	400万円以上	0.13	0.15	−0.050	0.16	0.14	0.058
	無回答	0.11	0.12	−0.036	0.11	0.12	−0.035
就労	就労している	0.18	0.23	−0.112	0.22	0.22	−0.014
	退職して現在就労していない	0.70	0.62	0.174	0.63	0.63	0.003
	職に就いたことがない	0.07	0.10	−0.099	0.11	0.10	0.040
	無回答	0.04	0.05	−0.041	0.04	0.05	−0.034
治療疾患の有無	あり	0.74	0.75	−0.025	0.77	0.75	0.026
	なし	0.20	0.19	0.032	0.18	0.19	−0.008
	無回答	0.06	0.06	−0.007	0.05	0.06	−0.036
主観的健康感	よくない	0.06	0.13	−0.228	0.13	0.12	0.025
	よい	0.91	0.84	0.190	0.84	0.85	−0.026
	無回答	0.03	0.03	0.025	0.03	0.03	0.007
BMI[b)]	18.5 kg/m^2 未満	0.06	0.08	−0.067	0.06	0.08	−0.050
	18.5–25 kg/m^2 未満	0.75	0.71	0.078	0.74	0.72	0.058
	25 kg/m^2 以上	0.17	0.18	−0.045	0.17	0.18	−0.025
	無回答	0.03	0.03	−0.002	0.02	0.03	−0.022
飲酒状況	飲む	0.47	0.43	0.090	0.43	0.44	−0.013
	飲まない	0.52	0.57	−0.086	0.57	0.56	0.015
	無回答	0.00	0.00	−0.040	0.00	0.00	−0.023
喫煙状況	吸う	0.04	0.11	−0.252	0.09	0.10	−0.038
	吸わない	0.96	0.89	0.260	0.91	0.90	0.048
	無回答	0.00	0.00	−0.063	0.00	0.00	−0.051
社会参加	なし	0.39	0.55	−0.318	0.53	0.52	0.025
（週 1 回以上）	あり	0.54	0.34	0.409	0.38	0.38	−0.004
	無回答	0.06	0.11	−0.153	0.09	0.10	−0.038
活動能力[c)]	非満点	0.47	0.58	−0.220	0.57	0.56	0.008
	満点	0.51	0.38	0.269	0.40	0.40	0.000
	無回答	0.01	0.04	−0.147	0.03	0.03	−0.026

a）the inverse probability of treatment weighting
b）body mass index
c）老研式活動能力指標の合計に基づく。

表3　よこはまウォーキングポイント事業（YWP）の参加状況と歩行時間，運動機能，うつとの関連

	IPTW[a]			重回帰分析		
	非標準化偏回帰係数	95%信頼区間	*P*	非標準化偏回帰係数	95%信頼区間	*P*
歩行時間（分/日）						
非参加群	0			0		
参加群	3.61	（1.04, 6.17）	0.006	3.84	（1.59, 6.08）	0.001
運動機能[b]（点）						
非参加群	0			0		
参加群	−0.13	（−0.23, −0.03）	0.010	−0.10	（−0.19, −0.004）	0.041
うつ[c]（点）						
非参加群	0			0		
参加群	−0.21	（−0.42, −0.01）	0.038	−0.08	（−0.26, 0.09）	0.354

2013年調査時の性，年齢，同居状況，教育年数，等価所得，就労，治療疾患の有無，主観的健康感，BMI，飲酒状況，喫煙状況，社会参加，活動能力で調整した。
a）the inverse probability of treatment weighting
b）「基本チェックリスト」の「運動器の機能向上」に関する5項目（No. 6〜10）の合計得点に基づく。
c）Geriatric Depression Scale 日本語15項目版による。

傾向であった。表2は，IPTWによる調整前後の標準化差を示した。3指標におけるIPTWによる調整前の標準化差は，0.1を上回る調整変数があったが，IPTWによる調整後の標準化差は，すべての調整変数で0.1未満となり，群間のバランスが取れていた。

2.　YWPの効果

表3にYWPへの参加の有無と歩行時間，運動機能，うつとの関連について，IPTWおよび重回帰分析の結果を示した。YWP参加群では，非参加群に比べて，歩行時間は有意に増加し（非標準化偏回帰係数［B］＝3.61，95%信頼区間［95% CI］：1.04，6.17），運動機能得点とうつ得点は有意に減少した（B＝−0.13，95% CI：−0.23，−0.03；B＝−0.21，95% CI：−0.42，−0.01）。また，重回帰分析による感度分析の結果，YWP参加群では，非参加群に比べて，歩行時間は有意に増加し（B＝3.84，95% CI：1.59，6.08），運動機能得点は有意に減少した（B＝−0.10，95% CI：−0.19，−0.004）。うつ得点は有意な関連が認められなかった（B＝−0.08，95% CI：−0.26，0.09）。さらに，「参加できない（入院中や体調不良などのため）」を分析対象から除外した感度分析も行った。その結果，非参加群（3,751人）の16.2%に相当する607人が分析対象から減少したことに伴い，運動機能得点とうつ得点では有意な関連が消失したが，点推定値は同様の傾向が認められた（それぞれ，B＝−0.08，95% CI：−0.18，0.01；B＝−0.08，95% CI：−0.26，0.11）。

Ⅳ　考　　察

本研究は，一自治体の高齢者を対象に，ウォーキングポイントによる取組が歩行時間の増加，運動機能の低下予防とうつの抑制に効果があるかを検証した。ウォーキングポイントに参加した高齢者は参加しなかった高齢者と比較して，2013年調査時の属性や健康状態などの背景要因のバランスを取った上でも，3年後の歩行時間が増加し，運動機能低下・うつが抑制されることが示された。

1.　YWPと歩行時間との関係

本研究では，YWP参加群は，非参加群と比較して，1日あたりの歩行時間が3.61分増加した。高齢者を対象としたウォーキングプログラムの先行研究では，3か月間の介入後に歩行量が増加したことが報告されている[12〜14]。Rosenberg et al.[12]の3か月間の介入研究では，ベースライン時と比較して3か月後の歩行量が1日あたり約500歩増加したことが報告されている。Tudor-Locke et al.[29]や厚生労働省[30]は1分あたりの歩数を100歩とし，Rosenberg et al.[12]は，高齢者の場合においても1分あたり約100歩で換算していることより，本研究の参加群は非参加群と比較して1日あたり約360歩増加したと考えられる。このことから本研究において，先行研究で確認された効果が，ウォーキングプログラム開始後最長2年間という長期間においても得られることが示唆された。

ウォーキングは，高齢者が取組やすい運動であり[8]，高齢者を対象にしたインセンティブの付与によるウォーキングを含む運動プログラムでは，身体活動の促進や歩行量の増加に効果があること[5,31]が本研究においても追試された。さらに，身体活動に関する介入研究や健康増進を目的とした場合に歩数

計を用いることは，身体活動の動機付け[32]や歩行量の増加に有効とされている[33]。本研究の参加群においてもウォーキングは取組やすく，インセンティブの付与や歩数計の使用が，ウォーキングに対する動機付けを高め，歩行時間の増加につながったと考えられる。

2. YWPと運動機能との関連

本研究では，YWP参加群は，非参加群と比較して運動機能の低下が抑制されたことが示された。加藤ら[34]は，二次予防事業の対象者に対する3か月間のウォーキングを含む運動器機能向上プログラムの効果を検証し，基本チェックリストの「運動器の機能向上」に関する項目[25]，開眼片足立ち，歩行能力やバランスなどの機能的移動能力を評価するTimed Up & Go Test（TUG）[35]，および5 m通常/最大歩行時間が有意に向上したことを報告している。また，地域在住高齢者を対象としたウォーキングを含む運動プログラムによる3〜10か月間の介入研究では，歩行速度[14]，階段昇降の速度[15]，TUG[13,16]，バランス機能[15]や下肢筋力[14]が有意に向上し，転倒回数が対照群と比較して少ないことが報告されている[16]。これらの先行研究は，ウォーキングを含む運動プログラムが，本研究で測定した「運動器の機能向上」に関する項目[25]の階段昇降，立ち上がり動作，歩行能力の改善や転倒予防に効果的であることを示している。

本研究において，YWPへの参加は，ウォーキングの促進や歩行能力および筋力の維持や改善につながり，非参加群と比較して参加群の運動機能低下を抑制したと考えられる。このことから本研究において，3〜10か月間の介入による先行研究と同様の効果が，最長2年間の観察期間においても得られることが示唆された。

3. YWPとうつとの関連

本研究では，YWP参加群と非参加群の背景要因をIPTWによりバランスを取った結果，YWP参加群は非参加群と比較して，うつ得点の増加が抑制されたことが示された。Smith et al.[36]は，ベースライン時に歩行距離が長い高齢男性は，8年後のうつを発症するリスクが低いことを報告している。また，地域在住高齢者を対象にしたウォーキングを含む運動プログラムによる6週間〜4か月間の介入研究では，プログラム後にうつが減少したことが報告されている[19,37]。本研究はこれらの先行研究と類似した結果が示された。

ウォーキングを含む運動プログラムは，精神的健康に良い影響があり[14]，余暇としてのウォーキングは楽しみなどにつながる[38]。また，近隣でのウォーキングの頻度が多いほど，社会参加が増加する[39]ことより，ウォーキングを通して社会的相互作用が向上し，うつの改善につながることが考えられる。本研究においてもYWPの参加により，身体活動の機会や社会的相互作用が増加し，精神的健康が改善され，うつ得点の増加の抑制につながったと考えられる。

4. 臨床的および社会的重要性・意義

本研究では，個人としての歩行時間や運動機能得点とうつ得点の差は小さいが，集団として考えた場合に，以下の効果が考えられる。約300歩に相当する1メッツ・時/週の増加で，死亡リスクが約1%減少することが報告されている[40,41]。本研究においてYWP参加者の歩行量は一人あたり1日約360歩増加したことより，YWP参加により死亡リスクを約1%減少することが期待できる。運動機能得点は，集団として約8人，うつ得点は集団として約5人がYWPに参加した場合，1点分の改善効果が見込まれる。また，本研究のYWP参加者は全対象者の16.8%であることより，横浜市のYWP参加高齢者は，横浜市の高齢者人口92万人のうち15万人と推定される。国土交通省の推定値によると，歩行量が1日1,500歩増加した場合，年間の医療費が約3万5千円減少することが報告されている[42]。一人あたり1日約360歩増加をYWP参加高齢者15万人に当てはめた場合，1日約5,400万歩増加に相当し，これは年間約12.6億円の医療費削減が期待できる。これらのことから，YWPは，高齢者のポピュレーションアプローチとしての介護予防効果が見込まれる取組である。

5. 本研究の強みと限界

本研究の強みは，地域代表サンプルを用いて，IPTWによる疑似ランダム化を行い，ウォーキングポイントが高齢者の健康に効果的であることを検証したことである。しかしながら，本研究にはいくつかの限界がある。第一にYWPの参加状況は2016年調査の質問項目で尋ねているため，YWPへの参加期間が不揃いである。また，ウォーキングの強度や頻度に関する情報が不明である。このため，対象者によっては，ウォーキングの期間や量や質が異なる可能性があり，本研究で検討した3つの健康状態において，最適なウォーキングの頻度や期間，強度について詳細に検討できなかった。さらに，自記式質問紙調査であり，歩行時間や運動機能については客観的なデータを用いていないため，測定バイアスの可能性がある。ウォーキングに参加した対象者は，自治体より歩数計が配布されていたが，本研究では歩数計による客観的なデータが利用できなかった。

今後は，ウォーキングの強度や頻度，期間を考慮し，歩数計などの客観的なデータを用いた検討が期待される。第二に，本研究の結果は，都市部の一自治体に在住する要介護認定を受けていない高齢者を対象者としているため，一般化可能性に限界がある。歩きやすい地域や都市部では，高齢者の身体活動量の低下が少ないことが報告されており[43]，都市部と農村部，あるいはインセンティブの違いによってウォーキングポイントが高齢者の健康に及ぼす効果が異なる可能性がある。今後は，都市部以外に農村部，インセンティブが異なる複数の自治体を含めて検討する必要がある。第三に，個人の予防・健康づくりに向けたインセンティブを提供する取組に係るガイドライン[2]にある「健康無関心層」の行動や意識変容にどの程度有効であったか，高学歴や高所得層において効果が大きい結果，健康格差を拡大していないか，また横浜市民における YWP の認知度，コンプライアンスや継続率などが不明である。今後は，これらも考慮した検討が期待される。第四に，IPTW によって擬似ランダム化した本研究の結果が，ランダム化比較試験で検証されることが望まれる。ただし，このような行政のプログラムにおいてランダム化比較試験を行うことは，現実社会では極めて困難と考えられる。

V　結　　語

本研究は，横浜市の地域代表性のある高齢者を対象にしたデータによって，ウォーキングポイント事業への参加が，参加者と非参加者の背景要因に対して傾向スコアを用いてバランスを取った上でも歩行時間の増加や運動機能の低下予防，うつの抑制に効果があることが示唆された。ウォーキングを主とする自治体による健康ポイント事業は，対象者を選別しないポピュレーションアプローチとして高齢者の健康増進に役立つ取組であると考えられる。

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Effectiveness of walking point projects with incentives for walking time, physical function, and depression among older people: inverse probability of treatment weighting using propensity scores

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Key words: older adults, incentives, walking, propensity scores

Objectives This study aimed to examine the effectiveness of a walking point project with incentives for increasing walking time, preventing the decline of physical function and worsening depression among older adults.

Methods We used data from the Japan Gerontological Evaluation Study, which included subjects aged ≥65 years who lived in Yokohama City in 2013 and 2016. We obtained information on the subjects' participation in the "Yokohama Walking Point (YWP)," a program launched by Yokohama City in 2014, from the 2016 survey data. We excluded individuals with missing data for sex, age, walking time per day (<30, 30–59, 60–89, or ≥90 min/day), physical function (5 physical function category items on the Kihon Checklist), depression (15-item Geriatric Depression Scale), and participation status in the YWP. We used data from 4,509 eligible respondents. Changes in walking time, physical function, and depression were designated as independent variables, and participation status in the YWP was designated as the dependent variable in the multiple regression analysis with inverse probability of treatment weighting (IPTW), after adjusting for demographic variables, socioeconomic status, health status, and behavior.

Results Among the total subjects, 758 (16.8%) participated in the YWP. The IPTW method showed that participants in the YWP had significantly higher walking times (B=3.61, 95% CI: 1.04, 6.17), less decline in physical function, and less depression (B=−0.13, 95% CI: −0.23, −0.03; B=−0.21, 95% CI: −0.42, −0.01) than those who did not participate in the YWP.

Conclusions Our findings suggest that the YWP, with incentives, effectively increased walking time and prevented worsening of physical function and depression among older adults. The municipality's health point project, based on the number of steps, is a useful population approach for promoting health among older adults.

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特集 次代の公衆衛生を展望する

健康格差に対する日本の公衆衛生の取り組み—その到達点と今後の課題

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【ポイント】

◆「健康日本 21(第 2 次)」の中間評価において「健康格差の縮小」や「社会環境の整備」では前進がみられた.

◆今後は,「ゼロ次予防」を目指し, 市町村や社会階層間の健康格差, ライフコース, 建造環境,「health in all policies」に着目すべきである.

◆evidence based policy making(EBPM)の推進のため, 健康影響予測評価とプログラム評価, ロジックモデル, 評価計画などが課題となる.

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ORIGINAL ARTICLE

Dementia risk by combinations of metabolic diseases and body mass index: Japan Gerontological Evaluation Study Cohort Study

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Keywords
Dementia, Metabolic diseases, Underweight

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ABSTRACT

Aims/Introduction: To compare the dementia risk associated with pre-existing diabetes, hypertension, dyslipidemia, obesity (body mass index [BMI] ≥25 kg/m^2) and underweight (BMI <18.5 kg/m^2) among older adults. We also explored the dementia risk associated with combinations of metabolic diseases and BMI.

Materials and Methods: We used data from the Japan Gerontological Evaluation Study. Participants completed a health checkup in 2010 and were followed for 5.8 years on average. Dementia was measured by municipal long-term care insurance registration. Diabetes, hypertension, dyslipidemia, obesity and underweight were diagnosed by medication use or health examination results. We calculated the incidence of dementia and adjusted hazard ratios (HRs).

Results: Among 3,696 participating older adults, 338 developed dementia. Adjusted HRs (95% confidence intervals) in men and women (reference: those without corresponding disease of normal weight) were as follows: 2.22 (1.26–3.90) and 2.00 (1.07–3.74) for diabetes; 0.56 (0.29–1.10) and 1.05 (0.64–1.71) for hypertension; 1.30 (0.87–1.94) and 0.73 (0.49–1.08) for dyslipidemia; 0.73 (0.42–1.28) and 0.82 (0.49–1.37) for BMI of 25–29.9 kg/m^2; and 1.04 (0.51–2.10) and 1.72 (1.05–2.81) for underweight. Dementia risk was significantly higher in underweight men with dyslipidemia (HR 4.15, 95% CI 1.79–9.63) compared with normal-weight men without dyslipidemia, and in underweight women with hypertension (HR 3.79, 1.55–9.28) compared with normal-weight women without hypertension. Dementia incidence was highest among underweight older adults with hypertension followed by dyslipidemia.

Conclusions: Among Japanese older adults, underweight and prevalent diabetes are risk factors for developing dementia. Lower BMI is also associated with a higher incidence of dementia.

INTRODUCTION

Dementia is a prevalent disease in older adults worldwide[1]. Researchers have investigated the dementia risk related to metabolic diseases[2]. Diabetes is known to impair cognitive function through several mechanisms[3–8], and there is debate as to whether hypertension in late-life increases or decreases the incidence of Alzheimer's disease[9,10]. Hypercholesterolemia might be a risk factor for dementia in mid-life, but not in late life[11]. Although dementia risk might increase with overweight or obesity in mid-life (relative risk 0.99–2.44)[12], the estimated risk for dementia associated with obesity in late-life varies (relative risk 0.24–1.13)[12]. However, separating individual dementia risk factors might be difficult, because metabolic diseases and obesity frequently overlap in older adults.

Being underweight might also be a risk factor for a reduced lifespan[13]. The Rotterdam Study carried out in the Netherlands suggested that a body mass index (BMI)

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<18.5 kg/m^2 (underweight) in older adults increased mortality[14]. A USA study reported high mortality among residents aged ≥65 years who were underweight or had unintentional weight loss[15]. Korean[16] and Japanese[17] older adults with low to normal-to-low BMI might also be at risk for a shorter lifespan. However, little is known about dementia risk among underweight older adults.

Some Asian older adults are underweight because of undernutrition[18] and underexercising[19], which might result in a shorter lifespan. Although Asians tend to be slimmer than Caucasians[20], they have a similar prevalence of diabetes and dyslipidemia[8,21,22]. Analyses of dementia risk associated with metabolic diseases and BMI have been carried out separately. However, evaluation of the risk for dementia among people with coexisting metabolic diseases and obesity/underweight is required. The present study aimed to compare the dementia risk associated with diabetes, hypertension, dyslipidemia and BMI (obesity and underweight) in a Japanese cohort. We also aimed to clarify the combinations of metabolic disease and BMI that had the highest risk for developing dementia.

METHODS

Participants

In 2010, the Japan Gerontological Evaluation Study randomly selected community-dwelling adults aged ≥65 years who were not registered by municipalities at baseline as requiring care under the long-term care insurance (LTCI) system[23]. In Japan, adults with incident dementia at age ≥40 years are covered by LTCI[24]. The benefits of LTCI range from support need levels 1 and 2 to care need levels 1–5[25], with a higher level indicating more care is required. As we describe below, the primary outcome of the present study was LTCI registration, diagnosis of dementia and a ranking of independence in daily life of ≥2b. Although a small number of participating older adults might have had slightly impaired cognitive function[24] at baseline, most were considered not to have dementia.

The present study included a subset of participants from the Japan Gerontological Evaluation Study cohort who received municipal health checkups in 2010 and were followed up over several years (average 5.8 years). Participants in this study were residents of Tokoname City and Minamichita Town in Aichi Prefecture, Japan, which had approximately 59,000 and 18,000 residents in 2018, respectively. In the health checkups, trained nurses measured blood pressure, collected blood samples and interviewed participants regarding prescribed medications. Serum cholesterol and glycated hemoglobin A1c levels were measured using laboratory testing devices with every-morning calibrations. BMI was calculated as the participant's weight in kilograms divided by their height in meters squared.

The protocol for this research project was approved by the suitably constituted ethics committees of the study institutions, and conformed to the provisions of the Declaration of Helsinki (ethics committee of the Chiba University School of Medicine, approval no. 2493; the ethics committee of the University of Yamanashi School of Medicine, approval no. 18150). Informed consent was obtained from all participants and/or their legal guardian(s). Data for participating older adults were anonymously analyzed and reported.

Measurements

Since 2000, all Japanese people aged ≥40 years have been required to pay a premium for coverage under the LTCI system[26]. This meant that they would be eligible for insurance benefits if they required long-term care, including dementia care[27]. When people need dementia care under this system, they are required to submit documentation prepared by a medical doctor and a LTCI certification investigator (accredited by the prefecture) who visit the older adult's home. These documents record dementia diagnosis and score for independence in daily life, which is ranked as 1, 2a, 2b, 3a, 3b, 4 or M; a higher rank indicates more dependence on others for assistance. For example, rank 2a indicates that the person has difficulty in daily life with symptoms, behaviors and communication outside the home (e.g., they might frequently lose their way or make mistakes with payments), but can lead an independent life with some care and support. If the difficulties described in rank 2a are both outside and inside the home, the person would be ranked 2b. Rank 4 indicates the older adult requires constant care. Therefore, we defined patients with dementia as those who had started to receive the LTCI benefit and were ranked from 2a to 4 as the outcome for the time-to-event analysis. Rank M indicates that people require specialized medical care for severe psychiatric symptoms, problematic behaviors or severe physical disorders; few people are certified with this rank, and we could not measure and include rank M as an outcome in the present study.

Health examinations that participants received in their municipalities were carried out by medical staff in medical institutions. We extracted data for diabetes, hypertension, dyslipidemia, underweight and obesity from the results of these examinations. Diabetes was defined as receiving the relevant medication or glycated hemoglobin A1c ≥6.5% (48 mmol/mol) according to a recommended guideline for epidemiological studies[28]. Hypertension was defined as receiving medication, systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg[29]. Dyslipidemia was defined as receiving medication, serum low-density lipoprotein cholesterol ≥140 mg/dL, high-density lipoprotein cholesterol <40 mg/dL or triglyceride ≥150 mg/dL[30]. BMI was categorized as underweight (<18.5 kg/m^2), normal weight (18.5–24.9 kg/m^2) or obese (≥25 kg/m^2), according to the recommended cut-off values for Japan[31,32]. When the sample size was sufficient for analysis, we further divided the obesity range to 25–29.9 kg/m^2 (obesity grade 1) or ≥30 kg/m^2 (obesity grades 2–4)[31,32].

Statistical analysis

We described participants' baseline characteristics using means (standard deviations [SD]) or numbers (percentages for proportions). We calculated hazard ratios (HR) with 95% confidence intervals (CI) for developing dementia for those with diabetes, hypertension, dyslipidemia, obesity and underweight stratified by sex. The HRs were adjusted for age, history of stroke, educational background, income, number of family members, marital status and frequency of meeting friends. As a sensitivity analysis, we carried out this analysis excluding the explanatory variable of history of stroke. We also calculated crude HRs for combinations of three metabolic diseases and BMI. In calculating HRs, participants who were lost to follow up were treated as censored data. Because dementia development was relatively common among underweight older adults, we calculated the dementia incidence rate (100 person-years) in those with and without diabetes, hypertension, and dyslipidemia to explore the profile with the highest risk. We also presented the incidence of dementia for combinations of three metabolic diseases and BMI. In this analysis, we calculated the *P*-value for trend for the association between BMI and total incidence of dementia, and that in each metabolic disease profile. Participants who had all data for the explanatory and response variables, and censored time were included in the analyses. All statistical analyses were carried out with SAS version 9.4 (SAS Institute Inc., Cary, NC, USA). Descriptive statistics were reported as means and SDs. We used the SAS PROC PHREG procedure to calculate HRs. All reported *P*-values were two-sided; *P*-values < 0.05 were considered statistically significant.

RESULTS

Table 1 shows the baseline characteristics of participants who were followed up. In total, there were 3,696 participants (42.8% men); 338 developed dementia. Participants' mean age at baseline was 73.4 years (SD 5.8 years), and the mean follow-up duration was 5.8 years (SD 1.3 years). Dyslipidemia was the most common and obesity the second most common among three metabolic diseases and BMI abnormalities (obesity and underweight).

Table 2 shows the HRs for developing dementia with diabetes, hypertension, dyslipidemia, obesity and underweight by sex. Men and women with diabetes had a statistically significant doubled risk for dementia compared with those without diabetes. Underweight women had a HR for dementia of 1.72 compared with those with normal weight, and this result was statistically significant. None of the covariates for adjustment were significantly associated with the incidence of dementia. In the sensitivity analysis excluding the explanatory variable of history of stroke, HRs (95% CIs) in men and women were as follows: 2.21 (1.26–3.88) and 2.00 (1.07–3.74) for diabetes; 0.65 (0.35–1.23) and 1.02 (0.62–1.66) for hypertension; 1.31 (0.88–1.95) and 0.72 (0.49–1.07) for dyslipidemia; 0.90 (0.12–6.52) and 0.62 (0.09–4.44) for BMI $\geq$30 kg/m^2; 0.74 (0.42–1.28) and 0.81 (0.49–1.36) for BMI 25–29.9 kg/m^2; and 1.04 (0.51–2.1) and 1.73 (1.06–2.83) for BMI <18.5 kg/m^2, respectively.

Table 3 shows the HRs for dementia in various combinations of metabolic diseases and body types stratified by sex. In brief, there was a statistically significant large HR in underweight men with dyslipidemia (HR 4.15, 95% CI 1.79–9.63) compared with normal-weight men without dyslipidemia. In addition, the large HR for underweight women with hypertension (HR 3.79, 95% CI 1.55–9.28) was statistically significant compared with normal-weight women without hypertension.

Table 4 shows the incidence rate for combinations of metabolic diseases and BMI. The highest incidence was in underweight participants with hypertension, followed by underweight participants with dyslipidemia. There were statistically significant trends of lower BMI and a higher incidence of dementia in all participants, and in those without diabetes, with hypertension, without hypertension, with dyslipidemia and without dyslipidemia.

Table 5 shows the results of Table 4 stratified by sex. There were statistically significant trends of lower BMI and a higher incidence of dementia in both sexes, and in men and women without diabetes, women with hypertension, men and women without hypertension, men and women with dyslipidemia, and men and women without dyslipidemia.

DISCUSSION

The present study showed that among older adults with metabolic diseases and body types, those with diabetes had the highest HR for dementia (Table 2). Among the various metabolic disease and body type profiles, underweight participants with hypertension had the highest incidence of dementia, followed by underweight participants with dyslipidemia (Table 4). In the combinations of metabolic disease and body type by sex, the highest HR was found in underweight men with dyslipidemia, followed by underweight women with hypertension (Table 3). Among all participants, lower BMI was associated with a higher incidence of dementia (Tables 4,5).

Previous research has shown that prevalent diabetes increased the risk for dementia, and one-third of general older adults have cerebrovascular amyloidosis[33]. In a mouse model, amyloidosis manifested significantly in mice with diabetes compared with those without diabetes[34]. Epidemiological studies have shown that people with diabetes are at 1.5–1.7-fold greater risk for dementia than people without diabetes[2,35]. Presumed mechanisms for the high dementia incidence in patients with diabetes include oxidant stress from steep glycemic excursion and production of reactive oxygen species[4], reduction of insulin transportation to the brain[5,7], inflammation of cerebral tissue, reduction of insulin signaling[6], and atherosclerosis from hypertension and hypercholesterolemia[8]. Consistent with previous studies, participants with diabetes in the present study had a doubled risk for dementia (Table 2). These data suggest that controlling diabetes in older adults would contribute to reducing the risk for dementia.

Table 1 | Baseline characteristics of participating Japanese older adults who were followed up in this study

Baseline characteristics of followed older adults	Men (n = 1,582)	Women (n = 2,114)
Age, years (mean ± SD)	73.4 ± 5.7	73.5 ± 5.8
BMI ≥30 kg/m^2, n (%)	20 (1.3)	49 (2.3)
BMI 25–29.9 kg/m^2, n (%)	336 (21.2)	417 (19.7)
BMI 18.5–24.9 kg/m^2, n (%)	1,134 (71.7)	1,462 (69.2)
BMI ≤18.4 kg/m^2, n (%)	92 (5.8)	186 (8.8)
Diabetes, n (%)	146 (9.2)	127 (6.0)
Hypertension, n (%)	277 (17.5)	389 (18.4)
Dyslipidemia, n (%)	752 (47.5)	961 (45.5)
Medication for diabetes, n (%)	51 (3.2)	40 (1.9)
Medication for hypertension, n (%)	201 (12.7)	282 (13.3)
Medication for dyslipidemia, n (%)	73 (4.6)	150 (7.1)
History of stroke, n (%)	32 (2.0)	19 (0.9)
Dementia, n (%)	131 (8.3)	207 (9.8)
Follow-up duration, years (mean ± SD)	5.7 ± 1.4	5.9 ± 1.2

BMI, body mass index; SD, standard deviation.

Table 2 | Hazard ratios (95% confidence intervals) for dementia in older adults with diabetes, hypertension, dyslipidemia, obesity and underweight

Metabolic disease	Univariate	Adjusted in model 1†	Adjusted in model 2†
Men			
Diabetes	1.42 (0.84–2.39)	1.72 (1.01–2.90)	2.22 (1.26–3.90)
Hypertension	0.74 (0.45–1.22)	0.63 (0.37–1.07)	0.56 (0.29–1.10)
Dyslipidemia	1.09 (0.77–1.53)	1.36 (0.96–1.93)	1.30 (0.87–1.94)
BMI ≥30 kg/m^2	0.58 (0.08–4.12)	0.66 (0.09–4.72)	0.91 (0.13–6.64)
BMI 25–29.9 kg/m^2	0.62 (0.38–1.02)	0.72 (0.44–1.18)	0.73 (0.42–1.28)
BMI 18.5–24.9 kg/m^2	Ref	Ref	Ref
BMI <18.5 kg/m^2	1.64 (0.90–2.98)	0.95 (0.52–1.75)	1.04 (0.51–2.10)
Women			
Diabetes	1.76 (1.11–2.79)	2.16 (1.36–3.44)	2.00 (1.07–3.74)
Hypertension	1.00 (0.70–1.42)	1.10 (0.77–1.58)	1.05 (0.64–1.71)
Dyslipidemia	0.68 (0.51–0.90)	0.88 (0.66–1.18)	0.73 (0.49–1.08)
BMI ≥30 kg/m^2	0.63 (0.20–1.99)	0.85 (0.27–2.66)	0.61 (0.09–4.43)
BMI 25–29.9 kg/m^2	0.75 (0.51–1.11)	0.81 (0.55–1.19)	0.82 (0.49–1.37)
BMI 18.5–24.9 kg/m^2	Ref	Ref	Ref
BMI <18.5 kg/m^2	1.99 (1.35–2.92)	1.52 (1.03–2.24)	1.72 (1.05–2.81)

†Model 1 adjusted for age and history of stroke; model 2 adjusted for model 1 plus educational background, income, number of family members, marital status and frequency of meeting friends. BMI, body mass index.

The present study also showed that underweight women were at risk for dementia (Table 2). We further analyzed our data to answer the question, "Which groups of underweight individuals with comorbid metabolic diseases suffer from dementia?" (Table 3). The results suggested that underweight men with dyslipidemia and underweight women with hypertension had a higher risk for dementia. These older adults might therefore need to be targeted for interventions for metabolic diseases to reduce dementia risk.

Reasons for older adults being underweight might include combinations of shortage of food intake, underexercising, digestion and absorption disorders, loss of teeth, endocrinological diseases, and debilitating diseases (e.g., cancer or infection)[36]. In particular, undernutrition among older adults has been recognized as a major reason for decline in muscle mass and weight[37]. A previous study showed that muscle-releasing hormones (myokines) played an important role in recovery of injured brain tissue, and exercise improved cognitive performance[38]. The high risk for dementia among those with low BMI in the present study emphasized the importance of maintaining muscle mass to preserve cognitive function[39]. This suggests that it might be important to encourage older adults to consume more protein than younger to middle-aged adults[40].

Table 3 | Hazard ratios for dementia in older adults with combinations of diabetes, hypertension, dyslipidemia, obesity, and underweight

DM	HT	DL	BMI	No.†	vs	DM	HT	DL	BMI	No.†	HR (95% CI)
Men											
(+)			Obese	5/48	vs	(–)			NW	88/1,038	1.17 (0.48–2.89)
(+)			Underweight	0/2	vs	(–)			NW	88/1,038	–‡
	(+)		Obese	3/85	vs		(–)		NW	84/948	0.38 (0.12–1.21)
	(+)		Underweight	0/6	vs		(–)		NW	84/948	–‡
		(+)	Obese	17/228	vs			(–)	NW	57/629	0.80 (0.47–1.38)
		(+)	Underweight	6/19	vs			(–)	NW	57/629	4.15 (1.79–9.63)
(+)	(+)		Obese	1/16	vs	(–)	(–)		NW	77/800	0.94 (0.24–3.72)
(+)	(+)		Underweight	0/1	vs	(–)	(–)		NW	77/800	–‡
(+)		(+)	Obese	4/37	vs	(–)		(–)	NW	51/576	1.34 (0.53–3.38)
(+)		(+)	Underweight	0/0	vs	(–)		(–)	NW	51/576	–‡
	(+)	(+)	Obese	3/67	vs		(–)	(–)	NW	50/549	0.43 (0.14–1.39)
	(+)	(+)	Underweight	0/0	vs		(–)	(–)	NW	50/549	–‡
(+)	(+)	(+)	Obese	1/15	vs	(–)	(–)	(–)	NW	47/509	–‡
(+)	(+)	(+)	Underweight	0/0	vs	(–)	(–)	(–)	NW	47/509	–‡
Women											
(+)			Obese	5/39	vs	(–)			NW	126/1,384	1.37 (0.56–3.35)
(+)			Underweight	0/10	vs	(–)			NW	126/1,384	–‡
	(+)		Obese	4/112	vs		(–)		NW	112/1,204	0.37 (0.14–1.01)
	(+)		Underweight	5/19	vs		(–)		NW	112/1,204	3.79 (1.55–9.28)
		(+)	Obese	15/249	vs			(–)	NW	89/803	0.52 (0.30–0.91)
		(+)	Underweight	9/53	vs			(–)	NW	89/803	1.68 (0.85–3.34)
(+)	(+)		Obese	0/11	vs	(–)	(–)		NW	102/1,051	0.52 (0.11–2.40)
(+)	(+)		Underweight	0/2	vs	(–)	(–)		NW	102/1,051	0.74 (0.24–2.33)
(+)		(+)	Obese	2/21	vs	(–)		(–)	NW	79/768	0.74 (0.24–2.33)
(+)		(+)	Underweight	0/2	vs	(–)		(–)	NW	79/768	–‡
	(+)	(+)	Obese	3/94	vs		(–)	(–)	NW	75/718	0.30 (0.11–0.83)
	(+)	(+)	Underweight	2/8	vs		(–)	(–)	NW	75/718	2.69 (0.91–7.91)
(+)	(+)	(+)	Obese	0/9	vs	(–)	(–)	(–)	NW	67/691	0.24 (0.01–4.67)
(+)	(+)	(+)	Underweight	0/0	vs	(–)	(–)	(–)	NW	67/691	–‡

†Number of dementia onset/number of aged adults at risk. ‡Hazard ratio could not be calculated because of the small sample size. Hazard ratios for dementia in older adults with one to several metabolic disease(s) were provided, compared with normal-weight older adults without corresponding metabolic disease(s), shown as (–). BMI, body mass index; CI, confidence interval; DL, dyslipidemia; DM, diabetes mellitus; HR, hazard ratio; HT, hypertension; NW, normal weight. Obese, body mass index ≥25 kg/m^2; normal weight, body mass index 18.5–24.9 kg/m^2; underweight, body mass index <18.5 kg/m^2.

Table 4 | Incidence of dementia (per 100 person-years) among older adults stratified by body mass index and disease

BMI (kg/m^2)	<18.5 (n = 278)	18.5–24.9 (n = 2,596)	25.0–29.9 (n = 735)	≥30.0 (n = 69)	P for trend
All	2.92	1.58	1.11	0.99	<0.0001
DM (+) (n = 273)	0	2.71	1.91	1.92	0.36
DM (–) (n = 3,423)	3.05	1.51	1.02	0.85	<0.0001
HT (+) (n = 666)	4.08	1.70	0.65	0	0.0002
HT (–) (n = 3,030)	2.82	1.56	1.25	1.36	0.0005
DL (+) (n = 1,713)	3.88	1.38	1.18	0.48	0.0015
DL (–) (n = 1,983)	2.59	1.75	1.01	1.54	0.0011

BMI, body mass index; DL, dyslipidemia; DM, diabetes mellitus; HT, hypertension.

Among the disease and body type profiles investigated, there was a significant increase in dementia in underweight women with hypertension (Tables 3,5). Reportedly, the BMI of Swedish women with ε4 allele of the apolipoprotein E gene (ApoE4$^+$), a major risk factor for Alzheimer's disease, declined after age 70 years[41]. This allele has also been associated with aortic

Table 5 | Incidence rate of dementia (per 100 person-years) among older adult men and women stratified by body mass index and non-communicable diseases

BMI (kg/m^2)	<18.5	18.5–24.9	25.0–29.9	≥30.0	*P* for trend
Men (*n*)	448	1,582	356	20	
All	2.44	1.52	0.96	0.88	0.004
DM (+) (*n* = 146)	0.00	2.11	1.86	0.00	0.36
DM (–) (*n* = 1,436)	2.51	1.47	0.82	1.04	0.002
HT (+) (*n* = 277)	0.00	1.41	0.65	0.00	0.12
HT (–) (*n* = 1,305)	2.62	1.55	1.05	1.41	0.013
DL (+) (*n* = 752)	6.30	1.45	1.35	0.00	0.020
DL (–) (*n* = 830)	1.52	1.58	0.28	2.61	0.029
Women (*n*)	186	1,462	417	49	
All	3.15	1.63	1.23	1.04	0.0002
DM (+) (*n* = 127)	0.00	3.42	1.99	2.88	0.45
DM (–) (*n* = 1,987)	3.35	1.55	1.16	0.78	<0.0001
HT (+) (*n* = 389)	5.54	1.91	0.65	0.00	0.0004
HT (–) (*n* = 1,725)	2.92	1.57	1.41	1.35	0.008
DL (+) (*n* = 961)	3.09	1.32	1.02	0.75	0.013
DL (–) (*n* = 1,153)	3.18	1.88	1.48	1.28	0.007

BMI, body mass index; DL, dyslipidemia; DM, diabetes mellitus; HT, hypertension.

stenosis[42]. The Rotterdam Study showed that residents with an abnormal increase in blood pressure from approximately age 55 years had a higher risk for future stroke[43]. In a USA study of aged adults, hetero- or homozygous ε4 allele(s) were detected in 38.7% of patients with Alzheimer's disease, 44.8% of those with cerebrovascular dementia and 24.1% of people without dementia. The present study did not identify Alzheimer's disease and ApoE4$^+$. However, we presume that this allele might have influenced the correlations among the decline in BMI, increase in blood pressure and high dementia risk.

In the present study, underweight men with dyslipidemia were also at a statistically significant high risk for dementia (HR 4.15, 95% CI 1.79–9.63; Table 3). However, some participants with dyslipidemia had received medications from mid- or late-life, whereas others had not received pharmacological interventions. A previous meta-analysis showed that statin use had a risk reduction of 38% and 24% in dementia and Alzheimer's disease, respectively[44]. This might suggest that early pharmacological intervention for middle-aged adults with dyslipidemia should be encouraged. With regard to high serum cholesterol levels, diet-induced hypercholesterolemia in white rabbits showed increased levels of brain amyloid beta protein and apolipoprotein E (clinical manifestations of Alzheimer's disease)[45]. A Finnish epidemiological study showed that hypercholesterolemia in mid-life was an independent risk factor for Alzheimer's disease[46]. However, there is no evidence that Japanese underweight older men have a high probability of untreated dyslipidemia. Dyslipidemia might contribute to dementia related to both Alzheimer's disease and stroke.

The present results showed that other than diabetes, no metabolic disease consistently presented a high risk for dementia (Tables 2,3). Epidemiological evidence suggests that metabolic syndrome might be an independent risk factor for dementia[47,48]. Accumulation of obesity, hypertension and hypercholesterolemia in mid-life increases the risk for dementia[49]. However, few studies have compared the risk for dementia in late-life in people with obesity versus non-obesity. The results of two USA studies investigating this topic were inconsistent[50,51], and another recent USA study suggested that higher late-life BMI was associated with a lower risk for dementia[52]. The present study investigating Japanese older adults showed that being underweight in late-life was a risk factor for dementia, whereas obesity was not (Table 5).

Hypertension in late-life is a risk factor for stroke and therefore cerebrovascular dementia, and was previously suspected to be a risk factor for Alzheimer's disease[53]. However, a recent systematic review did not detect late-life hypertension as a risk factor[9]. There is some consensus from diverse epidemiological results that hypercholesterolemia in mid-life might be an independent risk factor for Alzheimer's disease[54]. Literature suggests that ApoE4$^+$ might increase the serum lipid level[55]. However, evidence for the association between late-life dyslipidemia and dementia incidence is scarce. The present study concluded that hypertension and dyslipidemia in late-life were not consistent risk factors for dementia in all older adults (underweight to obese; Tables 2,5).

We found that obese women with dyslipidemia, and with dyslipidemia and hypertension were at statistically significant low risks for dementia (HR 0.52, 95% CI 0.30–0.91; HR 0.30, 95% CI 0.11–0.83, respectively; Table 3).The present results for separate metabolic diseases or BMI categories (Table 2) showed that obesity, hypertension and dyslipidemia were not risk or protective factors for dementia in women in late-life. The reason for the low HR (0.52) in women with obesity and

dyslipidemia is unknown. However, as the metabolic disease groups included participants who could afford medical care expenses for those diseases, Japanese older adult women with obesity might have a higher level of education[56] and a sufficient diet, and therefore good health status.

Adjusted HRs (Table 2) of diabetes for dementia in men (2.22, 95% CI 1.26–3.90) versus women (2.00, 95% CI 1.07–3.74) were similar, whereas the HR and incidence of underweight were higher in women (1.72, 95% CI 1.05–1.81) than in men (1.04, 95% CI 0.51–2.10). The present data also suggested that there was a higher incidence of dementia in women not with diabetes or dyslipidemia, but with hypertension (Table 5). The frequency of ApoE4^{+} appeared to be similar between Japanese men and women[57]. Worldwide, the incidence of Alzheimer's disease is considered to be similar between the sexes[58]. However, the incidence of Alzheimer's disease tends to be higher in women in Japan, although vascular dementia is similar in both sexes, as men die at a faster rate with aging[59]. The reasons for our finding of a higher dementia risk among underweight women are likely to be complex. For example, there are neuroanatomical, neurochemical, psychological, behavioral and cognitive differences between the sexes[58]. The susceptibility to risk factors for dementia might also differ between the sexes[60]. The design of the present study did not elucidate underlying reasons for the high incidence of dementia among underweight women with and without cardiometric factors.

Social role might also affect the difference between men and women in terms of the relationship between underweight and dementia. When older adult women experience decreased cognitive function, there might be a corresponding loss of a balanced healthy diet. In Japan, women are traditionally expected to cook meals for their families[61]. Therefore, it is likely that older adult men with dementia who have a spouse might have a good diet, whereas older adult women with dementia (with and without a spouse) might not have a healthy diet. A limitation of the present cohort study was that it was difficult to strictly exclude people with dementia from the baseline participants. The significantly larger HR (1.72) for underweight and dementia onset in women (Table 2) might reflect this situation. Furthermore, it might be less effective for health professionals to recommend protein intake and exercise to prevent sarcopenia and dementia progression for Japanese women with mild dementia.

Older adults tend to have decreased digestion and absorption capacity[36,62]. Without sufficient protein intake and exercise, they are prone to lose muscle mass[63]. Underweight is also considered to reflect inactivity, frailty and sarcopenia, which is defined as age-related decline of skeletal muscle, muscle strength and physical performance[64,65]. The present results showed that older underweight women were at a high risk for dementia (Table 2). It might be important to recommend exercise for older adults to better control comorbid metabolic diseases, and reduce the risk for dementia[9], coronary heart disease, stroke, type 2 diabetes and several forms of cancer[66].

People are becoming increasingly concerned about modifying obesity to prevent non-communicable diseases and cancer[67]. For older adults, major health outcomes are longevity and a healthy lifespan. Because older adults are vulnerable to illness, and have high mortality and weak organs, guidelines for disease prevention and management for middle-aged adults have recently been customized for older adults[29,30,68–73]. However, we consider that medical guidelines for older adult patients with various metabolic and debilitating diseases require systemic evaluation, so that mortality risk from reducing a single disease does not increase other mortality risks. Dementia[74], sarcopenia and frailty[75] present major mortality risks for older adults. Many guidelines for the prevention or management of diseases require health professionals to intervene with older adults based on their disease profiles. Furthermore, health professionals need to support their patients individually to accomplish longer healthy lifespans, consistent with the recommendations of various medical guidelines.

The present study had several strengths. First, metabolic diseases were identified in medical examinations, and the diagnostic standards applied in this study were based on guidelines used by medical doctors. Second, the sample size was relatively large, especially in the Japanese context where databases for usual medical treatment, municipal health examinations and long-term care for older adults are not usually linked. The linking of these databases enabled us to compare the risk for dementia among older adults with several metabolic diseases and different BMI groups, and evaluate which groups were at the highest risk (Tables 2,4,5). Further analyses with these linked databases are required to support the present results.

The present study also had several limitations. First, the endpoint (dementia) was gathered from municipal LTCI registrations, and it is possible that not all older adults with dementia applied to receive the LTCI benefit. As described in the Methods section, older adults with slightly impaired cognitive function might have been included as participants at baseline. However, as dementia progresses, patients tend to require support and it is therefore likely that patients or their caregivers would have applied for long-term care. Although this measurement of dementia onset might have been indirect, we consider that most cases of dementia onset were detected in this cohort. Second, the primary cause of dementia was not measured. For example, the etiology of cerebrovascular dementia differs from that of Alzheimer's disease, and the respective risk factors would be different. Third, the sample population was older adults living in two municipalities, and the results might not be generalizable. Fourth, it is possible that some older adults who were underweight at baseline were already mildly demented, and this might have impacted our findings. Fifth, the amount of muscle mass was not evaluated. A meta-analysis of randomized controlled trials of healthy older adults showed that exercise assisted in preserving reasoning ability[76]. Measurement of muscle mass is therefore likely to have improved the interpretation of the present results. Sixth, longitudinal changes in

metabolic disease profiles were not measured and built into the analyses. Finally, we did not adjust for risk factors for dementia other than history of stroke and metabolic status. However, we believe that overadjustment with many covariates would have biased the results, as would underadjustment. In addition, all cohort studies have such bias.

In conclusion, in a Japanese older adult population, being underweight and prevalent diabetes might be risk factors for dementia. Clinicians need to evaluate the reasons for their patients being underweight, and provide interventions according to their disease profiles.

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DISCLOSURE

The authors declare no conflict of interest.

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A prospective study of knee pain, low back pain, and risk of dementia: the JAGES project

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The aim of this prospective study was to investigate the associations of knee and low back pain with dementia development. Participants were 14,627 older people with no history of stroke, cancer, injuries, depression, Parkinson's disease, or dementia who did not require support for daily living completed self-administered questionnaires with 3-years follow-up. A Cox regression model was used to calculate hazard ratios (HRs) and 95% confidence intervals (CIs) for dementia development. Stratified analyses by age and regular walking were conducted. Dementia risk was higher in participants aged 65–79 years with knee pain and without low back pain than in those without knee and low back pain [HR: 1.73 (95% CI: 1.11–2.68)]. Dementia risk was lower in participants ≥80 years with low back pain but no knee pain than in those without low back or knee pain [HR: 0.50 (95% CI: 0.31–0.80)]. Participants with knee pain who did not walk regularly had the highest dementia risk [HR: 1.71 (95% CI: 1.26–2.33)]. Knee pain may increase dementia risk among individuals aged 65–79 years, and may further increase risk in non-regular walkers. Low back pain may be a marker of maintained cognitive function despite age for individuals ≥80 years.

Pain is a major cause of reduced activities of daily living (ADL)[1], which can increase dementia risk among older people. Thus, pain may be a dementia risk factor. However, previous study findings on pain and dementia are inconsistent. A prospective cohort study in the United States identified persistent pain as a risk factor for cognitive impairment and dementia[2], whereas pain was not associated with cognitive decline among older people in a prospective cohort study in the United Kingdom[3].

To explain this inconsistency, it may be useful to consider pain sites. Although both knee pain and low back pain can reduce ADL, they may differentially affect cognitive functions, and an investigation of the associations between knee/low back pain and dementia risk may be useful for dementia prevention. The only previous study on pain sites reported that osteoarthritis (OA) was independently associated with increased risk of dementia development[4]. However, the study did not consider physical activities or psychosocial factors, which are important for dementia development. Furthermore, no studies have investigated the association between low back pain and dementia risk.

Therefore, the aim of this Japanese prospective cohort study was to examine the associations of knee pain and low back pain with dementia development, considering physical activities, psychosocial factors, and differences in underlying mechanisms of knee/low back pain.

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Methods

Study population. We mailed self-administered questionnaires to older residents (aged ≥65 years) identified from official residential registers of 30 local governments throughout Japan at baseline in 2013. The questionnaires assessed the experience of knee pain and low back pain. Participation was voluntary. The response rate was 71.5%, which is comparable to other surveys of community-dwelling residents. Respondents were linked to the national long-term care insurance registry, which includes information about cognitive impairment based on in-home assessment by trained investigators (e.g. public health nurses)[5]. Under the Long-Term Care Insurance Act, all local governments in Japan retain data on cognitive impairment for all applicants of the national long-term care program.

We identified 17,290 participants who completed the questionnaires and did not received benefits from the national long-term care insurance at baseline. We excluded 1,745 participants with a history of stroke, cancer, injuries, depression, or Parkinson's disease, dementia at baseline, and we also excluded 918 participants who reported a need for support for daily living or who had missing ADL data. Data from 14,627 participants were analysed. None of the participants had a documented disability.

Knee pain and low back pain. We used two simple sequential yes/no questions to detect knee pain and low back pain.

Knee pain. "Have you had any pain around your knee during the last year? (yes)" and "Has your knee pain interfered with your daily activities? (yes)" defined knee pain.

Low back pain. "Have you had any pain around your low back during the last year? (yes)" and "Has your low back pain interfered with your daily activities? (yes)" defined low back pain.

Adjusted variables. *Demographic factors.* These were age (65–69, 70–74, 75–79, 80–84, or ≥85 years), sex, body mass index (10 percentiles), alcohol consumption (non-drinker, ex-drinker, or drinker), smoking (non-smoker, ex-smoker, or smoker), and history of diabetes mellitus and hypertension (yes or no).

The following single questions were used to measure drinking and smoking status: "Do you drink alcohol? –'Yes', 'Ceased drinking', or 'No'" and "Do you smoke? –'Yes', 'Ceased smoking', or 'No.'"

Socioeconomic factors. Education (<6 years, 6 to <9 years, 9 to <12 years, or ≥12 years), marital status (married, divorced, single, widowed, or other), income divided into quartiles of equivalised income in 2012, including tax: Q1 (men <1.31; women <1.23), Q2 (men 1.31–1.93; women 1.23–1.70), Q3 (men 1.94–2.46; women 1.71–2.46), Q4 (men 2.47–3.19; women 2.47–3.20), and Q5 (men >3.19; women >3.20) million Japanese yen [JPY]), employment status (employee, retired, or unemployed), loss events (loss of spouse, family member, close friend, or relative; yes or no), frequency of social interaction (≥4 per week, 2–3 per week, once a week, 1–3 per month, several times per year, or never), and frequency of going out (≥4 per week, 2–3 per week, once a week, 1–3 per month, several times per year, or never). Equivalised income was calculated by dividing the median value of the multiple-choice annual household income by the square root of the number of people living together. The annual household income question had 15 categories (<0.5, 0.5–0.9, 1–1.4, 1.5–1.9, 2.0–2.4, 2.5–2.9, 3.0–3.9, 4.0–4.9, 5.0–5.9, 6.0–6.9, 7.0–7.9, 8.0–8.9, 9.0–9.9, 10.0–11.9, and >11.9 million JPY). We defined low income as less than 1.22 million JPY of equivalised income above the poverty line in Japan in 2015[6].

Psychological factor. Mood or anxiety disorder (yes or no). When participants had 13 points or more in the Kessler Psychological Distress Scale (K6), they were considered to have mood or anxiety disorder[7].

Others. We additionally adjusted for knee pain or low back pain when we used low back pain or knee pain as a main exposure, respectively.

Definition of dementia development. We used data from a standardized in-home assessment carried out under the national long-term care insurance scheme established in 2000[5]. The primary assessment was conducted for applicants of the long-term care program by trained investigators dispatched from the certification committee in each municipality. During home visits, each applicant was assessed on their ADL and instrumental ADL status, cognitive function (e.g. short-term memory, orientation, and communication) and the presence of mental and behavioural disorders using a standardized government assessment manual[8].

Cognitive disability grade was categorized into eight levels: 0, I, IIa, IIb, IIIa, IIIb, IV, and M (0 = Independent, M = Needs constant treatment in a specialized medical facility). This cognitive impairment categorization strongly correlated with Mini-Mental State Examination scores (Spearman's rank correlation $r = -0.73$, $p < 0.001$)[9], and 'level I' corresponded with a 0.5 point rating on the Clinical Dementia Rating scale (specificity and sensitivity, 0.88)[10].

The certification committee also asked a panel of physicians to independently assess the applicants' cognitive disability levels to determine the applicants' care requirements[11]. The medical assessment was conducted independently of the in-home assessment[11]. In our analysis, we used the in-home assessment, but a previous study using some of the JAGES data found a high correlation between in-home assessment and the committee medical assessment (Pearson's correlation $r = 0.80$, $p < 0.001$)[12].

We defined cases more than IIa as dementia development, as validated by a previous study[13]. The standardized assessment manual for the cognitive disability in older people defines IIa as "individuals who had dementia-related symptoms, behavioural disturbance and/or difficulty in communication that limited daily living outside the home, but who were capable of daily living under someone's care"[8].

	Knee pain		Low back pain		No pain	Knee pain only	Low back pain only	Both knee and low back pain
	−	+	−	+				
Number	10785	3842	10375	4252	8964	1411	1821	2431
Age, year (SD)	72.8 (5.8)	74.9 (6.3)	73.0 (5.8)	74.1 (6.3)	72.8 (5.7)	74.6 (6.2)	72.8 (6.0)	75.1 (6.4)
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Women	5339 (49.5)	2444 (63.6)	5371 (51.8)	2412 (56.7)	4447 (49.6)	924 (65.5)	892, (49.0)	1520 (62.5)
Obese	2130 (19.8)	1194 (31.1)	2181 (21.0)	1143 (26.9)	1742 (19.4)	439 (31.1)	388, (21.3)	755 (31.1)
Drinker	4083 (37.9)	1143 (29.8)	3800 (36.6)	1426 (33.5)	3392 (37.8)	408 (28.9)	691, (37.9)	735 (30.2)
Current smoker	1195 (11.1)	324 (8.4)	1096 (10.6)	423 (1.0)	988 (11.0)	108 (7.7)	207, (11.4)	216 (8.9)
History of diabetes mellitus	1331 (12.3)	540 (14.1)	1298 (12.5)	573 (13.5)	1112 (12.4)	186 (13.2)	219, (12.0)	354 (14.6)
History of hyper tension	4934 (45.8)	2082 (54.2)	4799 (46.3)	2217 (52.1)	4059 (45.3)	740 (52.5)	875, (48.1)	1089 (55.2)
Did not graduate from high school	4001 (37.1)	1881 (49.0)	3969 (38.3)	1913 (45.0)	3337 (37.2)	632 (44.8)	664, (36.5)	1249 (51.4)
Single	250 (2.3)	53 (1.4)	232 (2.2)	71 (1.7)	217 (2.4)	15 (1.1)	33, (1.8)	38 (1.6)
Low income	2725 (25.3)	1404 (36.5)	2681 (25.8)	1448 (34.1)	2235 (24.9)	446 (31.6)	490, (26.9)	958 (39.4)
Retired, n (%)	6428 (59.6)	2177 (56.7)	6152 (59.3)	2453 (57.7)	5320 (59.4)	832 (59.0)	1108 (60.9)	1345 (55.3)
Lost partner in last year	1224 (11.4)	659 (17.2)	1109 (10.7)	774 (18.2)	927 (10.3)	182 (12.9)	297, (16.3)	477 (19.6)
Lost relative, family, or friends in last year	3397 (31.5)	1331 (34.6)	3238 (31.2)	1490 (35.0)	2765 (30.9)	473 (33.5)	632, (34.7)	858 (35.3)
Frequency of going out <1/week	247 (2.3)	162 (4.3)	235 (2.3)	176 (4.1)	191 (2.1)	44 (3.1)	56, (3.1)	120 (4.9)
Never meets friends or acquaintances	695 (6.4)	335 (8.7)	686 (6.6)	344 (8.1)	577 (6.4)	109 (7.7)	118, (6.5)	226 (9.3)
Mood or anxiety disorder	353 (3.3)	312 (8.1)	339 (3.3)	326 (7.7)	263 (2.9)	76 (5.4)	90, (4.9)	236 (9.7)
Knee pain	—	—	1411 (13.6)	2431 (57.2)	—	—	—	—
Low back pain	1821 (16.9)	2431 (63.3)	—	—	—	—	—	—
Lack of regular walking	2243 (20.8)	1138 (29.6)	2129 (20.5)	1252 (29.4)	1770 (19.8)	359 (25.4)	473, (26.0)	779 (32.0)

Table 1. Mean values and proportions for participant characteristics. Abbreviations: SD: standard deviation. Note: Definition of obese: body mass index ≥25.

Definition of regular walking. We assessed average walking time per a day (<30, 30–59, 60–89, and ≥90 minutes), and we defined walking time per a day ≥30 minutes as regular walking.

Statistical analysis. We calculated person-months of follow-up from baseline to the first endpoint: dementia, death, moving away from the local government area where they were registered, loss to follow-up, or administrative censoring at February 21, 2017.

Multivariable adjusted hazard ratios (HRs) with 95% confidence intervals (CIs) for dementia development according to existence of knee/low back pain were calculated using a Cox regression model. We also reran the main model after stratifying participants by age group or regular walking. As a sensitivity analysis, we reran the models after excluding participants suspected of mood or anxiety disorder (K6 ≥ 13 points) and those with both knee and low back pain.

P-values < 0.05 (two-tailed tests) were considered statistically significant. All statistical analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA).

Statement of ethics. All procedures were in accordance with the ethical standards of the Helsinki Declaration of 1975, as revised in 2013. All respondents were regarded as having provided their informed consent by returning the questionnaire. The Japan Gerontological Evaluation Study was approved by the Nihon Hukushi University Institutional Review Boards on human research (No. 13–14; date of approval: August 6, 2013). The title of the research was "The Japan Gerontological Evaluation Study (JAGES) project: the population-based large cohort."

Results

Table 1 shows the mean values and proportions for participant characteristics according to existence of knee pain or low back pain, and according to no pain, knee pain only, low back pain only, and both knee pain and low back pain during the past year. Compared with participants without knee pain or low back pain, those with knee pain or low back pain were more likely to be obese; to have high blood pressure, low income, and mood or anxiety disorder; to have lost a partner, relative, family, or friends in the last year; to go out less than once a week; and were less likely to be single, meet friends or acquaintances, and walk regularly.

In total, 482 (3.3%) developed dementia during follow-up. Table 2 shows the multivariable HRs for dementia development according to existence of knee or low back pain. Compared with participants without knee pain, those with knee pain had increased risk of dementia development [Model 6, HR 1.32 (95% CI: 1.06–1.64)].

In contrast, those with low back pain had decreased risk of dementia development compared with those without low back pain [Model 6, HR 0.79 (95% CI: 0.63–0.99)]. In model 1 and model 2 (the crude model and the sex-adjusted model), those with low back pain had an increased risk of dementia development. However, after adjusting for age, those with low back pain had a decreased risk of dementia development compared with those without low back pain. Therefore, we calculated HRs of dementia stratified by age group (Table 3). Both knee pain and low back pain increased the dementia risk among individuals aged ≤79 years, and decreased the dementia risk among individuals aged ≥80 years after adjusting for knee pain and low back pain.

	Knee pain		Low back pain	
	−	+	−	+
Total				
Person months	1008047.1	354044.7	96819.8	393922.0
Number of cases	298	184	322	160
Model 1 HR (95% CI)	1	1.77 (1.47–2.12)‡	1	1.22 (1.01–1.48)*
Model 2 HR (95% CI)	1	1.77 (1.47–2.13)‡	1	1.22 (1.01–1.47)*
Model 3 HR (95% CI)	1	1.21 (1.00–1.46)*	1	0.96 (0.79–1.16)
Model 4 HR (95% CI)	1	1.31 (1.06–1.62)*	1	0.85 (0.68–1.05)
Model 5 HR (95% CI)	1	1.39 (1.12–1.72)†	1	0.84 (0.68–1.05)
Model 6 HR (95% CI)	1	1.32 (1.06–1.64)*	1	0.79 (0.63–0.99)*

Table 2. Hazard ratios for dementia development according to knee pain and low back pain. Model 1: Crude model. Model 2: Adjusted for sex. Model 3: Adjusted for sex and age. Model 4: Adjusted for above-mentioned variables plus knee pain or low back pain. Model 5: Adjusted for above-mentioned variables plus body mass index, alcohol consumption, smoking, history of diabetes mellitus, and history of hyper tension. Model 6: Adjusted for above-mentioned variables plus education, marital status, equivalised income, employment status, loss events, frequency of going out, frequency of social interaction and mood or anxiety disorder. Abbreviations: HR: hazard ratio, CI: confidence interval. *$p < 0.05$, **$p < 0.01$.

		Knee pain			Low back pain	
	p for interaction	−	+	p for interaction	−	+
65–69 aged years						
Person months	—	345697.9	80076.4	—	315241.7	110532.7
Number of cases	—	30	4	—	29	5
Model 2 HR (95% CI)	—	1	N/A	—	1	N/A
Model 7 HR (95% CI)	—	1	N/A	—	1	N/A
70–74 aged years						
Person months	—	329330.5	105478.5	—	318097.8	116711.2
Number of cases	—	38	25	—	41	22
Model 2 HR (95% CI)	p = 0.01	1	2.09 (1.26–3.49)†	p = 0.02	1	1.47 (0.88–2.47)
Model 7 HR (95% CI)	p = 0.02	1	2.04 (1.14–3.64)*	p = 0.02	1	1.41 (0.93–2.15)
75–79 aged years						
Person months	—	199995.7	86935.5	—	199571.9	87359.30
Number of cases	—	53	39	—	57	35
Model 2 HR (95% CI)	—	1	1.72 (1.13–2.62)*	—	1	1.41 (0.92–2.15)
Model 7 HR (95% CI)	—	1	1.63 (1.01–2.64)*	—	1	1.11 (0.68–1.80)
80–84 aged years						
Person months	—	94293.8	55026.1	—	95807.3	53512.60
Number of cases	—	91	51	—	95	47
Model 2 HR (95% CI)	—	1	0.93 (0.66–1.32)	—	1	0.87 (0.62–1.24)
Model 7 HR (95% CI)	—	1	0.99 (0.67–1.47)	—	1	0.88 (0.59–1.30)
85–89 aged years						
Person months	—	31497.3	20941.6	—	32105.7	20333.30
Number of cases	—	59	44	—	72	31
Model 2 HR (95% CI)	—	1	1.11 (0.75–1.65)	—	1	0.67 (0.44–1.03)
Model 7 HR (95% CI)	—	1	1.45 (0.94–2.25)	—	1	0.56 (0.35–0.90)*
≥90 aged years						
Person months	—	7231.8	5586.7	—	7345.5	5473.00
Number of cases	—	27	21	—	28	20
Model 2 HR (95% CI)	—	1	1.15 (0.64–2.09)	—	1	1.03 (0.58–1.84)
Model 7 HR (95% CI)	—	1	1.18 (0.60–2.33)	—	1	0.95 (0.49–1.85)

Table 3. Hazard ratios of dementia stratified by age group. Model 2: Adjusted for sex. Model 7: Adjusted for sex and knee pain or low back pain. Abbreviations: HR: hazard ratio, CI: confidence interval. *$p < 0.05$, **$p < 0.01$.

Table 4 shows the multivariable HRs for dementia development according to no pain, knee pain only, low back pain only, and both knee pain and low back pain during the past year stratified by age group; 65–79 and ≥80 years old. Participants with knee pain only aged 65–79 years had an increased risk of dementia development [Model 9,

	No pain	Knee pain only	Low back pain only	Both knee and low back pain
Total				
Person months	837564.4	130605.4	170482.7	223439.3
Number of case	258	64	40	120
Model 1 HR (95% CI)	1	1.60 (1.21–2.10)‡	0.76 (0.55–1.06)	1.75 (1.41–2.17)‡
Model 2 HR (95% CI)	1	1.60 (1.21–2.11)‡	0.76 (0.55–1.06)	1.75 (1.41–2.17)‡
Model 3 HR (95% CI)	1	1.16 (0.88–1.53)	0.71 (0.51–0.99)*	1.14 (0.91–1.42)
Model 8 HR (95% CI)	1	1.25 (0.95–1.65)	0.72 (0.52–1.02)	1.20 (0.96–1.50)
Model 9 HR (95% CI)	1	1.20 (0.91–1.59)	0.69 (0.50–0.97)*	1.07 (0.84–1.34)
65–79 aged years				
Person months	729847.4	103063.9	14516.7	169426.4
Number of case	100	27	21	41
Model 9 HR (95% CI)	1	1.73 (1.11–2.68)*	1.04 (0.65–1.67)	1.39 (0.94–2.05)
≥80 aged years				
Person months	107717	27541.5	25306	54012.8
Number of case	200	52	30	103
Model 9 HR (95% CI)	1	0.94 (0.65–1.35)	0.50 (0.31–0.80)†	0.91 (0.68–1.22)

Table 4. Hazard ratios of dementia development according to no pain, knee pain only, low back pain only, and both knee pain and low back pain during the past year stratified by age group. Model 1: Crude. Model 2: Adjusted for sex. Model 3: Adjusted for sex and age. Model 8: Adjusted for above-mentioned variables plus body mass index, alcohol consumption, smoking, history of diabetes mellitus, and history of hyper tension. Model 9: Adjusted for above-mentioned variables plus education, marital status, equivalised income, employment status, loss events, frequency of going out, frequency of social interaction, and mood or anxiety disorder. Abbreviations: HR, hazard ratio; CI, confidence interval. *$p < 0.05$, ‡$p < 0.001$.

HR 1.73 (95% CI: 1.11–2.68)]. Those with low back pain aged ≥80 years had a decreased risk of dementia development [Model 9, HR 0.50 (95% CI: 0.31–0.80)].

Table 5 shows the multivariable HRs for dementia development stratified by regular walking. The associations of knee pain and low back pain with dementia risk were similar to the main results, regardless of regular walking. Individuals aged 65–79 years and ≥80 years who did not walk regularly and had knee pain had the highest dementia risk of the four groups (with/without knee pain; regular walking/no regular walking) [Model 6, HR: 1.91 (95% CI: 1.16–3.16), and HR: 1.63 (95% CI: 1.10–2.43), respectively]. Participants who experienced low back pain and did not walk regularly did not have an increased risk of dementia development compared with those with no low back pain who walked regularly.

The sensitivity analysis showed similar results to the main results (data not shown).

Discussion

In this sample of the Japanese general population, knee pain was prospectively associated with increased risk of dementia development particularly in individuals aged 65–79 years. The increased dementia risk in these individuals may be enhanced if they do not walk regularly. Low back pain was associated with reduced risk of dementia development among individuals ≥80 aged years, independent of physical activity, socioeconomic and psychosocial factors.

Knee pain among older people, which is usually caused by OA, is associated with inflammation[14,15]. Persistent inflammation damages cerebral blood vessels and induces neuroinflammation[14,15]. Research shows that both vascular dementia and Alzheimer's dementia are caused by inflammation[14,15]. Individuals with knee pain are likely to have a high sedative load, which can increase dementia risk. However, we suggest that knee pain (possibly accompanied by inflammation) itself, as well as physical inactivity, might increase dementia risk. Inflammation also contributes to some subtypes of low back pain, but the prevalence of inflammatory low back pain in one population-based study was only 5–6%[16].

A previous cohort study in Taiwan reported an association between OA and dementia development[4]. However, this previous observational study had several limitations. First, it used data from a health insurance database based on physicians' diagnoses in medical settings, and included only patients visiting hospitals or clinics; thus, the study did not consider individuals who had knee pain but did not consult a doctor. Second, this previous study did not account for socioeconomic and psychosocial factors in addition to physical activity; all of these are important risk factors for dementia. The present study did not have these limitations.

Approximately 85% of low back pain is a non-specific type of pain related to central nerve system[17]. A systematic literature review reported that OA pain including knee pain was also associated with central nerve system[18]. For a person to perceive a centralized pain, it is necessary for the prefrontal brain area to pay "sustained attention" to the pain[19], and sustained attention requires maintaining a certain level of brain function. For example, patients with cognitive disorder owing to dementia or Parkinson's disease often have decreased sustained attention[20,21]. Participants with low back pain aged ≥80 years had a decreased risk of dementia compared with those without low back pain. These findings may suggest that experiencing low back pain may be a marker of relatively maintained brain function among old-old people. We found that participants aged 65–79 years with knee pain only

			Knee pain			Low back pain	
		p for interaction	−	+	p for interaction	−	+
Regular walking	Person months of total		800788.7	250171.0		771816.7	279142.9
	Number of case		192	106		211	87
	Model 6 HR (95% CI)	0.52	1	1.38 (1.06–1.80)*	0.51	1	0.81 (0.62–1.07)
Lack of regular walking	Person months of total		207258.4	103873.7		196353.1	114779.1
	Number of case		106	78		111	73
	Model 6 HR (95% CI)	—	1.40 (1.10–1.80)†	1.71 (1.26–2.33)‡	—	1.40 (1.10–1.78)†	1.00 (0.74–1.34)
65–79 aged years							
Regular walking	Person months of total		704269.7	196443.2		672304.2	228408.8
	Number of case		85	41		89	37
	Model 6 HR (95% CI)	0.78	1	1.60 (1.06–2.43)*	0.60	1	0.96 (0.63–1.47)
Lack of regular walking	Person months of total		170754.3	76047.3		160607.2	86194.4
	Number of case		36	27		38	25
	Model 6 HR (95% CI)	—	1.31 (0.87–1.96)	1.91 (1.16–3.16)*	—	1.34 (0.91–1.99)	1.09 (0.66–1.79)
≥80 aged years							
Regular walking	Person months of total		96518.9	53727.8		99512.6	50734.2
	Number of case		107	65		122	50
	Model 6 HR (95% CI)	0.71	1	1.25 (0.88–1.75)	0.80	1	0.72 (0.50–1.04)
Lack of regular walking	Person months of total		36504.1	27826.5		35745.9	28584.7
	Number of case		70	51		73	48
	Model 6 HR (95% CI)	—	1.44 (1.05–1.98)*	1.63 (1.10–2.43)*	—	1.42 (1.04–1.94)*	0.96 (0.66–1.40)

Table 5. Hazard ratios of dementia stratified by regular walking. Model 6: Adjusted for age, sex, body mass index, knee pain or low back pain, alcohol consumption, smoking, history of diabetes mellitus, history of hyper tension, education, marital status, equivalised income, employment status, loss events, frequency of going out, frequency of social interaction, and mood or anxiety disorder. Abbreviations: HR, hazard ratio; CI, confidence interval. *$p < 0.05$, †$p < 0.01$, ‡$p < 0.001$.

had an increased risk of dementia, but those aged ≥80 years did not. Although inflammation related to knee pain may increase dementia risk, experiencing knee pain may be associated with maintained brain function particularly for old-old people; thus, old-old people (unlike other generations) may not have an increased risk of dementia.

One of the strengths of the present study is that we used a community-based prospective large cohort study design. However, the study has several limitations. First, data on the development of dementia were obtained from the results of an examination and assessment for a national Long-Term Care scheme. Residents aged ≥40 years with specific diseases and all residents aged ≥65 years can apply for the long-term care program if they wish; participants with dementia development who did not apply for the national long-term care program were not identified. Therefore, the number of individuals with dementia development might have been underestimated. Second, we were unable to differentiate dementia type (e.g., vascular or Alzheimer's dementia). Analysis of pathological information may have elucidated the mechanisms underlying the associations found here. Third, we did not measure pain intensity and therefore could not examine dose–response relationships between low back and knee pain and dementia risk. Fourth, we did not collect information about medical treatments. Treatment for pain, dementia, and other comorbidities may affect dementia development; however, we could not examine this potential confounding effect.

In conclusion, knee pain may increase dementia risk among Japanese older people aged 65–79 years, and this increased dementia risk may be enhanced if they do not walk regularly, independent of socioeconimic and psychosocial factors. Experience of low back pain may be a marker of maintained cognitive function despite age in old-old people aged ≥80 years, independent of physical activity, socioeconomic and psychosocial factors.

Data Availability

All enquiries should be addressed to the data management committee via e-mail: dataadmin.ml@jages.net. All JAGES datasets have ethical or legal restrictions for public deposition owing to inclusion of sensitive information from the human participants. Following the regulation of the local governments that cooperated with our survey, the JAGES data management committee has imposed restrictions upon the data.

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Author Contributions

Design and conceptualized study, analyzed the data and drafted the manuscript for intellectual content (K.Y.); and interpreted the data, revised the manuscript for intellectual content (Y.K., T.T., K.S., H.I., N.K. and K.K.).

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Article

Association between Food Store Availability and the Incidence of Functional Disability among Community-Dwelling Older Adults: Results from the Japanese Gerontological Evaluation Cohort Study

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Abstract: This study sought to clarify the association between food store availability and the incidence of disability in older adults. This study utilized a population-based cohort study of independent Japanese adults aged ≥65 years, which was a 6 year follow-up of participants in the Japan Gerontological Evaluation Study. A total of 31,273 respondents were extracted. Food store availability was evaluated based on the existence of food stores within 500/1000 m of the home. We utilized participant-reported subjective measurement as well as geographic information system-based objective measurement for the evaluation. The incidence of disability was determined using municipal data on eligibility for long-term care insurance benefits. There were 7643 (24.4%) community-dwelling participants with low subjective food store availability and 5673 (18.1%) with low objective food store availability. During the follow-up period of 6 years, the cumulative incidence of disability was 20.9%, with a significant association between low subjective food store availability and increased disability. Participants who reported low subjective food store availability had a significantly higher likelihood of developing disability (hazard ratio = 1.18, 95% confidence interval: 1.11–1.25) than those who reported high subjective food store availability after adjusting for age, sex, sociodemographic status, environmental status, walking and going out, dietary food intake, body mass index, and comorbidities. Low subjective food store availability was associated with early onset of disability. Accessibility of food stores might contribute to maintaining a disability-free life.

Keywords: food environment; food stores; functional disability

1. Introduction

Life expectancy is increasing worldwide, with a resultant increase in the elderly population who are at high risk of physical frailty, sarcopenia, progressive functional disability, dependency, and institutionalization, and will have serious social, medical, and economic impacts [1]. Malnutrition is considered a major risk factor of frailty, sarcopenia, impairment, and disability [2]. The Asia-Pacific Clinical Practice Guidelines for the Management of Frailty provisionally recommend that screening should be performed for frail older adults who have unintended weight loss to identify possible reversible causes and that protein and caloric supplementation/food fortification should be considered in such individuals [3]. The clinical guidelines for sarcopenia state that appropriate nutritional intake could prevent the onset of sarcopenia and is therefore recommended [4].

Personal dietary habits, as well as accessibility to food in terms of whether a variety of foods can be obtained, are considered to affect nutritional status. Many older adults face obstacles to accessing food due to a decline in walking and movement ability. As humans, we eat every day, so the food environment can affect us all and has a great influence. People who reside far from a grocery store are reported to have a 25%–46% lower likelihood of healthy dietary habits than those with the most stores nearby among community-dwelling residents in the United States [5]; low subjective accessibility of food increases the risk of low dietary variability among community-dwelling older adults in Japan [6]. According to Sharkey et al., objective and subjective indices of accessibility to a food store, such as further distance to the nearest grocery store, food stores that stock a diverse array of fresh and processed fruit, or those with a wide assortment of fresh and processed vegetables, were associated with reduced regular intake of fruit and vegetables based on data from community residents in the United States [7]. Also, cohort data targeting community-dwelling older adults in Japan showed that living in a food environment located in a poor neighborhood can possibly lead to malnutrition [8], while improved access to food stores was associated with higher body mass index (BMI) [9].

Previous studies have shown that the food environment might impact incidence of mortality and dementia in older people [10,11]. If one's main reason for going out is to shop at a neighborhood grocery store, food store availability might influence the incidence of functional disability in many older adults. However, the relationship between food store availability and functional disability has not been sufficiently verified so far. This study sought to verify the association between food store availability and the incidence of functional disability among older community-dwellers.

2. Materials and Methods

2.1. Study Population

We used prospective cohort data of a large-scale population-based study that involved older Japanese people aged ≥65 years from the Japan Gerontological Evaluation Study (JAGES) [12].

Data from JAGES were collected from eight municipalities in four prefectures (Hokkaido, Yamanashi, Aichi, and Nagasaki). Baseline data were collected from August 2010 to January 2012. Self-administered questionnaires were sent by mail to independently living individuals in the relevant community. From 52,180 participants who had no certified need for long-term care insurance, we used data on 31,273 participants, after excluding participants with missing information on subjective and/or objective food store availability (20,907 participants). All the participants were duly notified that participation in the JAGES project was voluntary and that returning the completed questionnaire would be considered as consent to participate. Ethics approval (No. 13–14) was obtained from the Ethics Committee at our university.

2.2. Measurements and Variable Definitions

Subjective food store availability was evaluated based on a self-reported questionnaire. The questionnaire consisted of a single question on subjective food store availability: "How many food stores or facilities that sell fresh fruits and vegetables are within 1 kilometer of your house?", rated on

a 4-point scale ("none", "few", "some", "many") [6]. We defined "many" and "some" as high, and "few" and "none" as low subjective food store availability.

Objective food store availability was evaluated using geographic information system (GIS)-based methods [13]. Our study utilized 500 m mesh data from the Commercial Establishment Survey of the Ministry of Economy, Trade and Industry [14]. Food stores comprised department stores, general merchandise retailers, convenience stores, and specialty grocery stores. On the premise that all kinds of stores were uniformly distributed in the 500 m mesh, the number of stores along a straight line in a 500 m radius of the residence of each participant was then calculated according to the area of proportional distribution of the map area. All spatial calculations were performed with ArcGIS 10.1 software. Participants who had stores along a straight line within a radius of 500 m from the center of their residential community blocks were categorized as having high objective food store availability and those without stores within a radius of 500 m were categorized as having low objective food store availability. We defined 500 m or less as a reasonable "walkable" distance to a food store, which has been used in similar studies [15,16].

The primary outcome was functional disability, which we defined as certified need for care or support under the long-term care insurance system of Japan [17]. Follow-up of participants was carried out for 6 years based on their incident functional disability. Incident functional disability data was obtained from databases of public municipal long-term care insurance. Participants who had been recently certified as needing care or support through Japan's long-term care insurance system were deemed as having functional disability [18]. Eligibility for insurance certification is determined based on a national standardized procedure that includes a medical examination by a physician and assessment of physical status and cognitive function.

Demographic variables included age and sex in the baseline survey. Sociodemographic status, walking and going out, driving status, neighborly relationships, nutritional status, and comorbidities were evaluated with a self-reported questionnaire. Variables of social and demographic status were educational attainment, yearly income, living arrangements, employment status, and marital status. Yearly income was adjusted for household size, where income was divided by the square root of the number of individuals per household. Variables of walking as well as going out comprised daily walking time and frequency of going out. For nutritional status, variables were BMI and fruit/vegetable intake and meat/fish intake rate over the previous month. Standard BMI categories were then used to classify participants as obese, overweight, normal, or underweight [19]. Neighborly relationships were evaluated as described by Nakamura et al. [6] by asking about the kind of relationship they have with others in their neighborhood. The responses included the frequency of exchanging greetings or conversing with neighbors and borrowing/lending items, and based on the results, participants were classified as having either a high- or low-level relationship with their neighbors. Variables about comorbidities included therapy for medical conditions/symptoms and symptoms of depression. Multiple answers were permitted, and so participants were required to state whether or not they were at the time receiving medical treatment for malignancy, cardiac disease, stroke, high blood pressure, diabetes mellitus, arthropathy/neuralgia, traumatic fracture, pulmonary disease, and gastrointestinal disorder and dysphagia. Using the Geriatric Depression Scale-15 (Japanese version) [20], symptoms of depression in older adults were assessed and participants were classified into either a non-depressed or depressed group. Cognitive function was categorized as "decline" versus "no decline" and was evaluated with a self-reported questionnaire [21]. Also, we calculated the population density of habitable land in the residential school districts of each participant using the 2010 census results and data for land utilization tertiary mesh (2010) from the National Land Numerical Information of the Ministry of Land, Infrastructure, Transport and Tourism, based on a topographic map of Japan (1:25,000). All non-developed areas, such as rivers, lakes, forests, and wasteland, were excluded from the calculations. All covariates with missing data were classified as "missing." Categories for each variable are shown in Table 2.

2.3. Statistical Analysis

Baseline characteristics of the study participants were defined, and then multivariate cox regression analysis was applied to evaluate the association between food store availability and incident functional disability during the 6 years of follow-up. Four models were generated: Model 1: adjusted for age and sex; Model 2: further adjusted for sociodemographic status (educational attainment, marital status, and employment status, yearly income, and living conditions) as confounding factors to examine whether the relationship between food store availability and disability was independent of other aspects of environmental status; Model 3: additionally adjusted for environmental status (driving status, neighborly relationships, and population density) to investigate whether the relationship between food store availability and functional disability was independent of other environmental factors; and Model 4: further adjusted for walking and going out (daily walking time and rate of going out), dietary food intake (frequency of fruit/vegetable and meat/fish intake), BMI, and comorbidities (malignancy, heart disease, stroke, hypertension, diabetes mellitus, joint disease/neuralgia, traumatic fracture, respiratory disease, digestive disease, dysphagia, depression, and cognitive decline) as potential mediating factors linking food store availability to functional disability. Analyses were performed using SPSS Statistics 19 (IBM Corp., Armonk, NY, USA).

3. Results

Table 2 shows the baseline characteristics of the participants and the incidence of functional disability after the 6 year follow-up period. Among all participants (n = 31,273, mean age: 74.1 years), 20.5% worked, 84.2% lived with others, 70.1% were married, 7.6% were underweight, 32.5% had cognitive decline, 24.4% had low subjective food store availability, 18.1% had low objective food store availability, and cumulative incidence of functional disability after 6 years was 20.9%. Male, super-old (>80 years) and non-car users tended to have low subjective and objective food store availability. Participants with both low subjective and objective food store availability tended to have low rates of going out. The prevalence of comorbidities was similar between participants with low food store availability and those with high food store availability. Participants with low subjective and objective food store availability tended to have high functional disability.

Results of Cox regression analysis are shown in Table 3. Participants who reported low subjective food store availability had significantly higher likelihood of developing disability (hazard ratio = 1.20, 95% confidence interval: 1.13–1.27; $p < 0.001$) than those who reported high food store availability after age and sex adjustment (Model 1). These hazard ratios were unchanged and remained statistically significant following additional adjustments for sociodemographic and environmental status (Model 2,3). The hazard ratio was slightly reduced but remained statistically significant (hazard ratio = 1.18, 95% confidence interval: 1.11–1.25; $p < 0.001$) after further adjustment for potential mediating factors (walking and going out, nutritional status, and comorbidities) (Model 4). However, objective food store availability showed no significant association with disability after age and sex adjustment in Model 1 (hazard ratio = 0.98, 95% confidence interval: 0.92–1.05; $p = 0.61$). In addition, no significant difference in objective food store availability was evident between Model 2 (hazard ratio = 0.98, 95% confidence interval: 0.92–1.04; $p = 0.60$), Model 3 (hazard ratio = 1.00, 95% confidence interval: 0.93–1.06; $p = 0.82$) and Model 4 (hazard ratio = 1.00, 95% confidence interval: 0.94–1.08; $p = 0.84$).

Table 1. Baseline characteristics of participants and incidence of functional disability after 6 years.

		All Participants	Subjective Food Store Availability		Objective Food Store Availability	
		(*n* = 31,273)	Low (*n* = 7643)	High (*n* = 23,630)	Low (*n* = 5673)	High (*n* = 25,600)
Sex	Male	14,411 (46.1)	3227 (42.2)	11,184 (47.3)	2589 (45.6)	11,822 (46.2)
	Female	16,862 (53.9)	4416 (57.8)	12,446 (52.7)	3084 (54.4)	13,778 (53.8)
Age (years)	65–69	8255 (6.4)	2035 (26.6)	6220 (26.3)	1377 (24.3)	6878 (26.9)
	70–74	9644 (0.8)	2230 (29.2)	7414 (31.4)	1677 (29.6)	7967 (31.1)
	75–79	7390 (23.6)	1794 (23.5)	5596 (23.7)	1406 (24.8)	5984 (23.4)
	≥80	5984 (19.1)	1584 (20.7)	4400 (18.6)	1213 (21.4)	4771 (18.6)
Educational attainment (years)	<6	684 (2.2)	213 (2.8)	471 (2.0)	205 (3.6)	479 (1.9)
	6–9	13,719 (43.9)	3592 (47.0)	10,127 (42.9)	2912 (51.3)	10,807 (42.2)
	10–12	10,606 (33.9)	2447 (32.0)	8159 (34.5)	1622 (28.6)	8984 (35.1)
	≥13	5503 (17.6)	1160 (15.2)	4343 (18.4)	804 (14.2)	4699 (18.4)
	Others/missing	761 (2.4)	231 (3.0)	530 (2.3)	130 (2.3)	655 (2.5)
Employment status	Working	6420 (20.5)	1456 (19.1)	4964 (21.0)	1295 (22.8)	5125 (20.0)
	Retired	17,333 (55.4)	4057 (53.1)	13,276 (56.2)	2710 (47.8)	14,623 (57.1)
	Never worked	3532 (11.3)	1000 (13.1)	2532 (10.7)	708 (12.5)	2824 (11.0)
	missing	3988 (12.8)	1130 (14.8)	2858 (12.1)	960 (16.9)	3028 (11.8)
Yearly income (yen, millions)	<2.00	13,279 (42.5)	3378 (44.2)	9901 (41.9)	2643 (46.6)	10,636 (41.5)
	2.00–3.99	9645 (30.8)	2188 (28.6)	7457 (31.6)	1520 (26.8)	8125 (31.7)
	≥4.00	2732 (8.7)	584 (7.6)	2148 (9.1)	441 (7.8)	2291 (8.9)
	missing	5617 (18.0)	1493 (19.5)	4124 (17.5)	1069 (18.8)	4548 (17.8)
Living conditions	Live alone	4193 (13.4)	1143 (15.1)	3050 (13.0)	712 (12.6)	3481 (13.6)
	Live with others	26,330 (84.2)	6318 (83.2)	20,012 (85.5)	4833 (85.8)	21,497 (84.7)
	missing	487 (1.6)	130 (1.7)	357 (1.5)	90 (1.6)	397 (1.6)
Marital status	Married	21,908 (70.1)	5031 (65.8)	16,877 (71.4)	4006 (70.6)	17,902 (69.9)
	Widowed	6783 (21.7)	1926 (25.2)	4857 (20.6)	1209 (21.3)	5574 (21.8)
	Divorced	1197 (3.8)	314 (4.1)	883 (3.7)	184 (3.2)	1013 (4.0)
	Never married	713 (2.3)	195 (2.6)	518 (2.2)	123 (2.2)	590 (2.3)
	Other/missing	672 (2.1)	177 (2.3)	495 (2.1)	151 (2.6)	521 (2.0)
Driving status	Non-car users	7865 (25.1)	2392 (31.3)	5473 (23.2)	1772 (31.2)	6093 (23.8)
	Car users	10,328 (33.0)	2647 (34.6)	7681 (32.5)	2120 (37.4)	8208 (32.1)
	missing	13,080 (41.8)	2604 (34.1)	10,476 (44.3)	1781 (31.4)	11,299 (44.1)

Table 2. Baseline characteristics of participants and incidence of functional disability after 6 years.

		All Participants	Subjective Food Store Availability		Objective Food Store Availability	
		(*n* = 31,273)	Low (*n* = 7643)	High (*n* = 23,630)	Low (*n* = 5673)	High (*n* = 25,600)
Neighborly relationships	High level	21,653 (69.2)	5197 (68.0)	16,456 (69.6)	4224 (74.5)	17,429 (68.1)
	Low level	7532 (24.1)	1960 (25.6)	5572 (23.6)	1052 (18.5)	6480 (25.3)
	missing	2088 (6.7)	486 (6.4)	1602 (6.8)	397 (7.0)	1691 (6.6)
Frequency of going out	Everyday	16,031 (51.3)	3320 (43.4)	12,711 (53.8)	2352 (41.5)	13,679 (53.4)
	≥2 times/week	8750 (28.0)	2311 (30.2)	6439 (27.2)	1746 (30.8)	7004 (27.4)
	≤1 time/week	4759 (15.2)	1553 (20.3)	3206 (13.6)	1265 (22.3)	3494 (13.6)
	missing	1733 (5.5)	459 (6.0)	1274 (5.4)	310 (5.5)	1423 (5.6)
Daily walking time	≥1 h/day	9139 (29.2)	2127 (27.8)	7012 (29.7)	1731 (30.5)	7408 (28.9)
	<1 h/day	20,249 (64.7)	5007 (65.5)	15,242 (64.5)	3577 (63.1)	16,672 (65.1)
	Missing	1885 (6.0)	509 (6.7)	1376 (5.8)	365 (6.4)	1520 (5.9)
Frequency of meat/fish intake	≥1 time/day	12,126 (38.8)	2658 (34.8)	9467 (40.1)	2198 (38.7)	9928 (38.8)
	<1 time/day	17,273 (55.2)	4469 (58.5)	12,804 (54.2)	3148 (55.5)	14,125 (55.2)
	missing	1874 (6.0)	516 (6.8)	1358 (5.7)	327 (5.8)	1547 (6.0)
Frequency of vegetable/fruit intake	≥1 time/day	23,508 (75.2)	5495 (71.9)	18,013 (76.2)	42.7 (74.2)	1931 (75.4)
	<1 time/day	6075 (19.4)	1697 (22.2)	4378 (18.5)	1175 (20.7)	4900 (19.1)
	missing	1690 (5.4)	451 (5.9)	1239 (5.2)	291 (5.1)	1399 (5.5)
Body mass index	Underweight < 18.5	2367 (7.6)	589 (7.7)	1778 (7.5)	410 (7.2)	1957 (7.6)
	Normal 18.5–24.9	21,433 (68.5)	5228 (68.4)	16,205 (68.6)	3750 (66.1)	17,683 (69.1)
	Overweight 25–29.9	5767 (18.4)	1367 (17.9)	4400 (18.6)	1157 (20.4)	4610 (18.0)
	Obese ≥ 30	732 (2.3)	203 (2.7)	529 (2.2)	141 (2.5)	591 (2.3)
	missing	974 (3.1)	256 (3.3)	718 (3.0)	215 (3.8)	759 (3.0)
Comorbidities	Malignancy	1383 (4.4)	351 (4.6)	1032 (4.4)	229 (4.0)	1154 (4.5)
	Heart disease	3785 (12.1)	972 (12.7)	2813 (11.9)	677 (11.9)	3108 (12.1)
	Stroke	4.7 (1.3)	88 (1.2)	319 (1.3)	76 (1.3)	331 (1.3)
	Hypertension	12,330 (39.4)	3107 (40.7)	9223 (39.0)	2302 (40.6)	10,028 (39.2)
	Diabetes mellitus	2819 (12.2)	896 (11.7)	2923 (12.4)	644 (11.4)	3175 (12.4)
	Joint disease/ Neuralgia	1242 (4.0)	369 (4.8)	873 (3.7)	242 (4.3)	1000 (3.9)
	Traumatic fracture	2024 (6.5)	567 (7.4)	1457 (6.2)	4.3 (7.1)	1621 (6.3)
	Respiratory disease	652 (2.1)	163 (2.1)	489 (2.1)	123 (2.2)	529 (2.1)
	Digestive disease	307 (1.0)	87 (1.1)	220 (0.9)	50 (0.9)	257 (1.0)
	Dysphagia	191 (0.6)	74 (1.0)	117 (0.5)	34 (0.6)	157 (0.6)

Table 2. *Cont.*

		All Participants	Subjective Food Store Availability		Objective Food Store Availability	
		(*n* = 31,273)	Low (*n* = 7643)	High (*n* = 23,630)	Low (*n* = 5673)	High (*n* = 25,600)
Depression	Non-depressed	18,831 (60.2)	4056 (53.1)	14,775 (62.5)	3381 (59.6)	15,450 (60.4)
	Depressed	7285 (23.3)	2247 (29.4)	5038 (21.3)	1364 (24.0)	5921 (23.1)
	missing	5157 (16.5)	1340(17.5)	3817 (16.2)	928 (16.4)	4229 (16.5)
Cognitive function	Decline	10,158 (32.5)	2673 (35.0)	7485 (31.7)	1902 (33.5)	8256 (32.3)
	Not decline	21,115 (67.5)	4970 (65.0)	16,145 (68.3)	3771 (66.5)	17,344 (67.8)
Incidence of functional disability	Non-certification	24,741 (79.1)	5800 (75.9)	18,941 (80.2)	4451 (78.5)	20,290 (79.3)
	Certification	6532 (20.9)	1843 (24.1)	4689 (19.8)	1222 (21.5)	5310 (20.7)

Categorical data are expressed as a number (%).

Table 3. Hazard ratios with 95% confidence intervals for incident functional disability with objective and subjective food store availability.

		Model 1 HR (95% CI)	Model 2 HR (95% CI)	Model 3 HR (95% CI)	Model 4 HR (95% CI)
Subjective food store availability	High	Reference	Reference	Reference	Reference
	Low	1.20 (1.13 to 1.27)	1.20 (1.13 to 1.26)	1.20 (1.13 to 1.26)	1.18 (1.11 to 1.25)
Objective food store availability	High	Reference	Reference	Reference	Reference
	Low	0.98 (0.92 to 1.05)	0.98 (0.92 to 1.04)	1.00 (0.93 to 1.06)	1.00 (0.94 to 1.08)

HR hazard ratio, CI confidence interval, ref reference group. Model 1: Adjusted for age and sex. Model 2: Model 1 + adjustments for sociodemographic status (education attainment, marital status, employment status, yearly income, living situation). Model 3: Model 2 + adjustments for environmental status (driving status, neighborly relationships, and population density). Model 4: Model 3 + adjustments for walking and going out (daily walking time and rate of going out), dietary food intake (frequency of fruit/vegetable and meat/fish intake), body mass index, and comorbidities (malignancy, heart disease, stroke, hypertension, diabetes mellitus, joint disease/neuralgia, traumatic fracture, respiratory disease, gastrointestinal disease, dysphagia, depression, and cognitive decline).

4. Discussion

Low subjective food store availability was associated with early onset of disability among community-dwelling older adults, but this was not the case for objective food store availability. The association remained after adjustments for age, sex, sociodemographic and environmental status, walking and going out, nutritional status, and comorbidities.

As reported by Tani et al., subjectively lower accessibility of healthy food stores measured was associated with mortality [10] and dementia [11], however, they did not examine the association of food store availability and disability. To our knowledge, this is the first report that utilized large-scale data to assess the relationship between food store availability and the incidence of functional disability among older community dwellers.

Earlier studies on food store availability were mainly cross-sectional studies that were carried out in areas of low population density, and by inference in environments with a low food store density (e.g., United States, but the United Kingdom is an exception) [22]. Our study was conducted in Japan within a setting with a substantially high population density and high density of food stores, compared with settings of similar studies in the West.

Objective and subjective food store availability appear to have different meanings. Food access has five dimensions, comprising availability, accessibility, affordability, accommodation, and acceptability [23,24]. In our study, objective food store availability evaluated only availability of food stores. We found an association between subjective (but not objective) food store availability and onset of disability. This pattern was consistent with findings from previous study, which showed that healthy outcomes were more strongly associated with subjective evaluations of availability but not with objective evaluations [25,26]. Another previous study revealed a high level of mismatch between perceived and objective indices (14%) [25]. Even in areas with low objective food store availability, it is possible for evaluations of subjective food store availability to be high among individuals who have high walking ability, access to public transportation and/or mobile catering options, a person or persons who shops for food on their behalf, or who can grow their own food.

We hypothesized that a food environment that is subjectively evaluated is a better representation of individual differences in self-cultivated food, shopping behaviors, or accepting food from people living close by; not all of these could be addressed by objective evaluation. Several conditions could influence subjective food store availability, for example, traffic around the store, the form of the sidewalk (inclination, stairs), store opening hours/days, security around the store, attributes of other shoppers and store staff, price and assortment of goods, and the store environment (spaciousness of the shop, easy entry, existing amenities such as washrooms and material resources) [27].

The association between subjective food store availability and incidence of functional disability persisted after adjusting for potential mediating factors in Model 4 and could be attributed to other unobserved factors. We speculate that improved food store availability promotes activities of daily living, such as selection of food items, shopping, carrying items, and cooking, which could contribute to maintenance of activities of daily living. Moreover, there is a possibility that we could not subjectively recognize the food stores that sell only low-variety, distasteful, and low-quality foods. Lack of dietary variety has been significantly associated with the progression of frailty in community-dwelling older persons [28]. If food store availability is poor, there is a tendency to stock up on canned foods and ready-to-eat foods and this causes dietary imbalance. Increased opportunities to eat a variety of foods and maintain a well-balanced diet might be responsible for the maintenance of physical status and cognitive function in our study.

Our results suffered from the risk of reverse causation. Participants with many comorbidities and declined physical function might answer low availability of subjective food store and move to a place near the food store. Model 4 included the comorbidities taking the problem into account.

A strength of our study was that we evaluated the impact of subjective, as well as objective, food store availability on disability, investigating these relationships in a high-density setting; using a relatively large sample size added to the statistical power in detecting associations. Nevertheless, there were several limitations in our study. Firstly, the type and size of food stores or the variety,

quality, and price of food items were not considered, all of which are possibly significant factors for making healthy food choices. Secondly, the study area may not necessarily be a reflection of Japan as a whole. It is thus necessary for our findings to be reproduced in other regions, particularly in a larger metropolis. Thirdly, home-delivery meals or food services were not taken into account. Fourthly, there is a possibility that food store availability is a product of unmeasured proxy variables related to regional characteristics, such as regional economic affluence and the number of facilities where people gather, which were not adjusted for in the analysis. Fifthly, our database does not contain any time-dependent variables such as the change of food access over 6 years. Sixthly, the self-reported questionnaire that evaluated subjective food store availability did not ask about any other fresh foods than fresh fruits and vegetables. However, we speculated that food stores that sell fresh fruits and vegetables are highly likely to sell other fresh foods.

Low subjective food store availability was associated with early onset of disability, but low objective food store availability was not. Accessibility of food stores might contribute to maintaining a disability-free life. Studies that evaluate the mechanisms involved in the variations in these indices of food store accessibility are required in the future.

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Change in Municipality-Level Health-Related Social Capital and Depressive Symptoms: Ecological and 5-Year Repeated Cross-Sectional Study from the JAGES

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Abstract: Prevalence of depressive symptoms is lower in communities with greater social capital (SC). However, it is unclear whether a prevalence of depressive symptoms will decrease in communities where SC has increased. We investigated the relationship between the changes in municipality-level SC and depressive symptoms by using 5-year repeated cross-sectional data from the Japan Gerontological Evaluation Study. In 2010 and 2016, self-reported questionnaires were mailed to functionally independent residents aged 65 years or older living in 44 municipalities; valid responses were received from 72,718 and 84,211 people in 2010 and 2016, respectively. All scores were aggregated at the municipality level. The dependent variable was the change in the prevalence of depressive symptoms that were diagnosed with a 15-item Geriatric Depression Scale. Independent variables were the score of change in health-related SC indicators, e.g., social participation, social cohesion, and reciprocity. A multiple regression analysis was employed. The average prevalence of depressive symptoms decreased from 28.6% in 2010 to 21.3% in 2016. The increases in the percentages of sports group participation (B, −0.356), and reciprocity scores (B, −0.597) were significantly associated with the decrease in the prevalence of depressive symptoms after adjusting for potential confounding variables. Our findings suggest that community SC might be an intervention for protecting depressive symptoms in municipalities.

Keywords: depression; older adults; population approach; municipality level; social capital; Japan Gerontological Evaluation Study

1. Introduction

Depression is the most common mental disorder (CMD) worldwide. According to the World Health Organization [1], the estimated prevalence of depression is 4.4%. According to the literature, depression in older adults has been associated with poor quality of life [2], functional decline [3], dementia [4], and mortality [5]. Thus, preventing depression is a critical target.

Risk factors of depression in older adults include low education, acceptance of risky lifestyle practices (e.g., smoking, risk drinking, physical inactivity, and obesity), and chronic disease [6,7]. Recent findings have indicated that mental health including depression in late life might be protective in relation to social capital (SC) [8–11].

One should realize that SC is an umbrella term meaning that resources are accessed by individuals as a consequence of their membership status in a network or group [12]. The conception of SC is often measured using civic engagement, individual and community social networks, and trust in the community [13], which can all be divided into structured, cognitive, bonding, and bridging [12]. Furthermore, SC has two levels: individual and group. Individual-level SC refers to resources that individuals can access through individual egocentric networks. Group-level SC is an asset of the entire network and benefits individuals included therein [12].

Within SC, health-related SC has been commonly used to examine associations with health-related outcomes, including depressive symptoms [14]. Earlier works from De Silva [8] and Ehsan and De Silva [9] have reported a strong inverse correlation between individual-level cognitive SC and CMD. At the community level, researchers have reported that CMD was low where community-level cognitive SC was high for seven cross-sectional studies [8,9].

Much of the literature on the community level has been cross-sectional, and the scarcity of community SC and CMD research has been noted [8,9]. Ecological research is appropriate to assess the impact on an entire population that profits from the direct effect of SC on individuals [15]. Although SC has been demonstrated to be a modifiable factor [16,17], research has not determined whether decreases in community-level depression are related to increases in community SC.

The purpose of this study was to examine whether the prevalence of community-level depressive symptoms decreased in a community where health-related SC increased using an ecological design.

2. Methods

2.1. Data

We used repeated cross-sectional data derived from the Japan Gerontological Evaluation Study (JAGES). The JAGES is an ongoing cohort study investigating social and behavioral factors related to health decline, including mortality and onset of functional or cognitive impairment among individuals aged 65 years or older [18,19]. Our data were collected from two waves of the JAGES, namely, 2010-12 (2010) and 2016. The mean follow-up period was 5.3 years.

Self-reported questionnaires were mailed to independent residents not eligible to receive public long-term care insurance benefits. The questionnaires were mailed to 31 municipalities in the 2010 wave and 39 municipalities in the 2016 wave, and the questionnaires were collected from 112,123 and 196,436 participants, corresponding to response rates of 66.3% and 70.2%, respectively. Data from 21 municipalities were obtained at both time points, in 2010 (n = 80,318) and 2016 (n = 100,868), and we excluded (i) missing information on sex, age, depressive symptoms, and basic activity of daily living (BADL; 2010: n = 6056, 2016: n = 11,321) and (ii) individuals whose BADL was not independent (2010: n = 1544, 2016: n = 5336). In addition, ordinance-designated cities in Japan have wards with functions similar to municipalities. Therefore, we split the two ordinance-designated cities into 25 wards.

Consequently, we used data from 44 municipal units (n: 2010 = 72,718 (minimum: 352, maximum: 5915), 2016 = 84,211 (minimum: 418, maximum: 8721)). Random sampling methods were used in 34 municipal units, and complete enumeration survey methods were used in 10 municipalities.

From the 34 municipalities where the sampling methods were conducted, we tracked the participants of 2010 in 2016 to create panel data sets, and the data were oversampled.

Ethical approval for the study was obtained from the Nihon Fukushi University Ethics Committee (application number: 10-05), National Center for Geriatrics and Gerontology (application number: No. 992-2), and Chiba University Ethics Committee (application number: No. 2493).

2.2. Dependent Variables

For the dependent variables of this community-level ecological study, we calculated the difference between the prevalence of depressive symptoms by subtracting the depressive symptoms for 2010 from the depressive symptoms for 2016 for each municipal unit. We assessed depressive symptoms by using the Japanese short version of the Geriatric Depression Scale (GDS) (score range: 0–15; Cronbach's alpha = 0.80) developed for self-administrative surveys [20,21]. We followed the literature [22–24]; thus, mild or severe depressive symptoms (GDS ≥ 5) were the cutoff scores previously validated as a screening instrument for major depressive disorder with 96% sensitivity and 95% specificity [22].

2.3. Independent Variables

For the independent variables, we measured health-related SC in the 2010 survey and the 2016 survey, and the difference score was calculated by subtracting the scores for 2010 from the scores for 2016 for each municipal unit. We defined SC as "features of social organization, such as trust, norms, and networks, that can improve the efficacy of society by facilitating coordinated actions" [25], and health-related SC has been a commonly used concept in epidemiological studies [14]. We selected health-related SC based on the indicators in Saito et al. [14], which examined the validity of community-level SC for Japanese people 65 years or older.

Regarding social participation, we assessed the frequency of participation in volunteer groups, sports groups, and hobby groups [14]. We created two intervals. The first interval was as follows: <1 day/month and ≥1 days/month [10,14]. The second interval was as follows: <1 day/week and ≥1 days/week [26]. Regarding the frequency of contact with friends and acquaintances, this was divided into two categories: <1 day/month and ≥1 days/month [27]. Regarding social support, we surveyed emotional and instrumental support (i.e., providing and receiving). Social support was assessed by asking the following question "Do you have someone who listens to your concerns and complaints?" Providing instrumental support to others was evaluated using the question "Do you have someone you take care of when she or he is sick in bed?" These social support responses were dichotomized into yes and no [14].

In addition, we used SC scores developed by Saito et al. [14]. According to Saito's index, civic participation (five questions), social cohesion (three questions), and reciprocity (three questions) were calculated for each municipal unit. Civic participation refers to the level of residents' participation in community organizations and activities. Civic participation was originally comprised of five questions. However, because information on attachment to the community was not available in the 2010 wave, we calculated the score of civic participation based on three questions. Social cohesion pertains to the cognitive aspects of interpersonal trust. Reciprocity represents community social support.

2.4. Covariates

We age-standardized the all variables by applying direct methods to the Japanese demographical statistics of 1985, which the Ministry of Health, Labor and Welfare have been using as a standard of statistics [28]. For the adjusted variables, we measured socioeconomic status in the 2010 survey and the 2016 survey, and the score for 2010 was subtracted from the score for 2010 across each municipal unit. Socioeconomic status included change in proportion of living alone, change in proportion of people with an equivalized household income greater than 2 million yen [29], change in proportion of having an education level greater than 10 years [29], and change in the proportion of the employed.

2.5. Statistical Analysis

First, we compared the differences in the study variables between the two time points by using a paired-samples *t*-test. Second, we used multiple linear regression models to examine the association between change in health-related SC variables and change in depressive symptoms (GDS ≥ 5). The following two models were constructed. In the crude model, change in health-related SC and change in depressive symptoms were separately modeled, and Model 1 added the covariates of change for living alone, change in proportion with an education level (greater than 10 years), change in proportion of having income (greater than 2 million yen for equivalized household income), and change in employment compared with the crude model. Notably, we took advantage of the change in the two time points, which can control for time-invariant unobserved and observed confounding community characteristics [30]. Finally, in 34 municipal units out of 44 municipal units, we tracked the participants of 2010 in 2016 to create panel data sets. The data were oversampled and in 2016 for participants obtained in 2010, they show a survival bias that was one of the selection biases. For that reason, we conducted the comparison using an independent-samples *t*-test to assess whether there was any difference in the change over the 5 years in the group of the complete enumeration survey and the group comprised by some individuals in the oversampling survey. We added sex to the analysis of Model 1 in the multiple linear regression and further investigated the interaction with sex and each health-related SC. As a result, of the 14 items for health-related SC, only social cohesion showed a significant association with changes in municipal-unit-level depressive symptoms. For that reason, sex was analyzed collectively. All analyses were conducted using SPSS V. 25.0J (IBM Japan, Tokyo, Japan).

3. Results

Overall, the prevalence of depressive symptoms decreased in 2016 compared with 2010. Age-adjusted average prevalence of depressive symptoms decreased from 28.6% (standard deviation (SD): 3.4%) in 2010 to 21.3% (SD: 2.7%) in 2016.

Table 1 presents the age-adjusted comparison in 2010 and 2016 for each variable. Compared with 2010, in 2016, the percentages of respondents who were married, lived alone, had an educational history of more than 10 years, and were employed increased. Of the 14 health-related SC items, we observed an increase in nine items and a decrease in three items, and the association was significant.

Table 1. Age-adjusted descriptive statistics of community factors (municipal units = 44).

Variables	2010				2016					
	Minimum	Maximum	Mean	SD	Minimum	Maximum	Mean	SD	Difference (2016–2010)	*p* Values
% Depressive symptoms [a]	23.2	39.5	28.6	3.4	16.3	27.9	21.3	2.7	−7.3	<0.001
% Married	60.1	78.3	71.5	4.9	60.2	80.2	72.5	4.8	0.9	0.003
% Living alone	8.0	27.1	14.9	4.9	9.2	31.3	17.0	5.2	2.1	<0.001
% Education ≥10 years	32.4	81.0	59.3	14.2	41.8	84.4	69.5	11.4	10.2	<0.001
% Equivalent income ≥2,000,000 JPY	34.2	66.3	52.2	8.9	37.1	63.8	51.6	7.4	−0.5	0.185
% Employed	15.9	35.9	23.7	4.1	22.7	46.1	31.0	4.6	7.4	<0.001
% Volunteer group [b] (≥1 per month)	7.7	15.4	11.4	1.7	10.9	20.2	15.7	1.8	4.3	<0.001
% Sports group [b] (≥1 per month)	11.4	31.6	24.2	4.3	19.9	39.4	30.7	4.6	6.4	<0.001
% Hobby group [b] (≥1 per month)	26.6	48.6	39.0	5.3	27.5	45.5	38.9	4.8	−0.1	0.869
% Volunteer group [b] (≥1 per week)	3.0	8.8	5.5	1.4	4.7	10.5	7.6	1.5	2.1	<0.001
% Sports group [b] (≥1 per week)	8.6	26.3	19.3	3.5	12.7	31.5	23.9	3.8	4.6	<0.001
% Hobby group [b] (≥1 per week)	15.4	32.2	24.5	3.8	16.3	29.5	24.2	3.3	−0.3	0.394
% Frequency of contact with friends [b] (≥1 per month)	67.3	82.5	73.4	3.6	66.5	81.6	72.2	3.8	−1.2	0.002
% Receiving emotional social support	89.3	96.4	93.7	1.4	92.1	97.0	94.7	1.2	1.1	<0.001
% Providing emotional social support	88.6	94.9	92.6	1.4	90.4	96.6	93.9	1.3	1.3	<0.001
% Receiving instrumental social support	86.6	97.0	94.0	2.4	87.4	97.4	94.7	2.1	0.7	<0.001
% Providing instrumental social support	81.0	90.7	87.2	2.2	81.0	90.4	85.5	2.1	−1.7	<0.001
Civic participation	41.1	75.0	61.3	8.3	47.2	84.5	69.0	8.4	7.7	<0.001
Social cohesion	143.3	182.7	161.0	10.1	138.2	172.9	158.7	9.0	−2.3	<0.001
Reciprocity	185.6	201.1	196.1	3.2	189.7	203.7	198.3	2.9	2.2	<0.001

SD: Standard deviation. * All factors were adjusted for age using the direct methods. [a] Depressive symptoms were defined as prevalence of Geriatrics Depression Scale ≥5 points. [b] Percentage of respondents that participated in the group.

From 2010 to 2016, the prevalence of depressive symptoms decreased and much of the health-related SC increased.

Table 2 shows the crude and adjusted model for the multiple regression of changes in health-related SC with changes in depressive symptoms. Among the 14 indicators of health-related SC, a significant association was observed for 10 indicators. For example, change in sports group (≤1 days/week: B, −0.356), change in frequency of contact with friends (≤1 days/month: B, −0.440), and change in reciprocity (B, −0.597) after adjusting to the change in socioeconomic status all predicted health-related SC.

Table 2. Multiple linear regression of changes in a health-related social capital (SC) with changes in depressive symptoms [b] (n = 44).

Variables	Crude			Model 1 [d]		
	B	SE	p Values	B	SE	p Values
% Change in [a] volunteer group (≥1 per month)	−0.273	0.184	0.145	−0.203	0.168	0.236
% Change in [a] sports group (≥1 per month)	−0.270	0.123	0.033	−0.234	0.124	0.066
% Change in [a] hobby group (≥1 per month)	−0.341	0.103	0.002	−0.309	0.111	0.008
% Change in [a] volunteer group (≥1 per week)	−0.089	0.230	0.700	0.051	0.224	0.822
% Change in [a] sports group (≥1 per week)	−0.397	0.152	0.013	−0.356	0.157	0.030
% Change in [a] hobby group (≥1 per week)	−0.215	0.134	0.115	−0.124	0.134	0.361
% Change in [a] frequency of contact with friends (≥1 per month)	−0.507	0.108	<0.001	−0.440	0.124	0.001
% Change in [a] receiving emotional social support	−0.797	0.276	0.006	−0.688	0.271	0.015
% Change in [a] providing emotional social support	−0.992	0.168	<0.001	−0.938	0.163	<0.001
% Change in [a] receiving instrumental social support	−0.229	0.321	0.479	−0.765	0.331	0.026
% Change in [a] providing instrumental social support	−0.451	0.227	0.054	−0.676	0.196	0.001
Change in [c] civic participation	−0.218	0.065	0.002	−0.189	0.068	0.008
Change in [c] social cohesion	−0.081	0.083	0.333	−0.171	0.074	0.027
Change in [c] reciprocity	−0.562	0.135	<0.001	−0.597	0.127	<0.001
% Change in [a] living alone	0.041	0.231	0.859			
% Change in [a] educational attainment	−0.252	0.071	0.001			
% Change in [a] equivalent income ≥2,000,000 JPY	−0.154	0.120	0.207			
% Change in [a] employed	−0.116	0.140	0.414			

All factors were adjusted for age using the direct methods. [a] Percentage of 2016 subtracted by 2010. [b] Depressive symptoms were defined as prevalence of Geriatrics Depression Scale ≥5 points. [c] The value of 2016 subtracted by 2010. [d] Model 1 was adjusted for change in living alone, change in educational attainment (≥10), change in equivalent income (≥2,000,000 JPY) and change in employed.

An association was shown between increased health-related SC and decreases in the prevalence of depressive symptoms after adjustment for potential confounding variables.

Supplementary Table S1 shows health-related SC for a 5-year change based on the sampling methods used. In the municipal units where the complete enumeration survey was carried out and a group with some oversampling was observed, we confirmed whether the change in the value from 2010 to 2016 was different in the two groups. Of the variables used as the dependent variable and independent variables, only change in social cohesion showed a difference between the two groups. In the case of a change in social cohesion, we performed multiple regression analysis and added the sampling methods' difference as dummy variables to adjust for the variables. However, the results did not change.

4. Discussion

According to our review of the literature, this is the first study to use a repeated cross-sectional design to verify that increases in the municipal unit level of health-related SC, such as civic participation, social cohesion, and reciprocity, are related to decreases in the prevalence of depressive symptoms in the municipal unit level.

Our results demonstrate that the prevalence of depressive symptoms after 5 years decreased by an average of 7.3% points. Another study reported a secular trend in the average score of GDS using the complete enumeration survey in the same district of older adults. According to the results,

the average score gradually decreased for men and women from 2003 to 2012 (GDS score annual average decrease value: men—0.001, women—0.09) and decreased significantly in women, and the reason for improvement was the influence of disability prevention project [31]. Furthermore, depression is a risk factor for suicide [7], and the suicide rate declined from 2010 to 2016 in Japanese older adults [32]. Therefore, there is a strong possibility that the prevalence of depressive symptoms is decreasing nationwide in Japan. The results of this study support these reports.

The health-related SC increased with many indicators from 2010 to 2016. According to previous studies, a secular trend is found for the index of Social Interaction using the complete enumeration survey in the same district of older adults [33]. According to that study, even though the interest in health-related SC increased over the last 20 years, SC in the form of social participation and social support did not change over those 20 years. One reason for the increase from 2010 to 2016 in this study could be the influence of Japanese disability prevention projects.

Since 2015, the disability prevention project in Japan has undergone a major policy change from a high-risk approach to a population strategy [34]. Disability prevention activities focusing on participation in activities are being promoted as one of the action policies. According to the records of the Ministry of Health, Labor and Welfare [35], places where older people can easily be active and participate increased from 43,154 in 2013 to 76,492 in 2016, which is, 1.77 times in 3 years. Notably, the number of people participating has also increased, from 840,718 in 2013 to 1,439,910 in 2016, which is, 1.71 times in 3 years. However, these numbers likely underestimate the actual numbers because they are merely the numbers captured by the municipality, not the total numbers. In addition, older people participate in activities such as sports and hobby groups in private clubs, but municipal units are unaware of the participants' presence. Thus, the number of participants is increasing even in places where the municipality does not comprehend; hence, the number of participants that actually exist is expected to be higher.

The JAGES provided evidence for this policy change [19], and the collaborating municipal units are eager to consider this effort. The increase in the number of places where older people can easily be active and participate will lead to an increase in older people who engage in activities and participation, and this increase in people's connections may have led to the increase in health-related SC from 2010 to 2016.

By considering the association between SC type and change in depressive symptoms, we showed an association between the decrease in depressive symptoms for increases in structural SC and cognitive SC. Regarding the structural SC, social participation and frequency of contact with friends were extracted from this factor. In the systematic review, the structural SC of the area was not related to CMD [9], whereas a structural SC, such as a sports group, a hobby group, and civic participation, showed a decrease in depressive symptoms in the current study.

In another study of JAGES, structural SC was divided into vertical and horizontal categories based on the result of factor analysis [36]. In vertical organizations, authority and resources are related hierarchically, whereas these two concepts are related equally in horizontal organizations. In relation to depression, a study demonstrated that the prevalence of depressive symptoms was low in areas where a high percentage of horizontal organizations, such as sports groups, adjusted individuals' participation in a cross-sectional manner [10]. In longitudinal studies, older people living in districts rich in horizontal organization have reported few depressive onsets 3 years later [11].

In this study, structural SC may be related to the decrease in depressive symptoms because it deals with the horizontal structure through the structural SC. Social networks, such as the frequency of contact with friends, are known to affect health through psychosocial mechanisms. Regarding connection and mental health, happiness as a network phenomenon that extends up to three degrees of separation was reported (e.g., to the friends of one's friends' friends) [37].

For cognitive SC, an association was observed between an increase in social cohesion and reciprocity and a decrease in the prevalence of depressive symptoms. Another study reported that community-level cognitive SC and CMD are inversely associated [9]. By contrast, longitudinal research

suggested that social cohesion and reciprocity at the community level were not associated with the onset of depression after 3 years [11]. As this study verified the association between change in health-related SC and change in depressive symptoms, the differences in the study designs might explain the different results. Further research is necessary.

These known mechanisms for community-level SC, namely (1) social contagion, (2) informal social control, and (3) collective efficacy, are the mechanisms that affect individual health [12]. In addition to those mechanisms, people's connections may have formed a network of social support and reduced the prevalence of depressive symptoms. Regarding the relationship between people's connections and depressive symptoms, a low prevalence of depressive symptoms in a community with high social support was reported [38]. A meta-analysis suggested that nonprofessional support is effective for reducing depressive symptoms [39], and it supported the association of community social support with depression. Due to the increase in municipal units' level of health-related SC, the prevalence of municipal units' level of depressive symptoms may decrease through the aforementioned route.

5. Strengths and Limitations

This research has two strengths. The first strength is that the prevalence of depressive symptoms decreased, whereas health-related SC increased. This result was based on a longitudinal study using a large population with a wide range of urbanites and 150,000 people in 44 municipal units with various characteristics. The second strength was that we verified the validity of a core indicator of an age-friendly city.

The results of this research may contribute to core indicators of socioenvironmental factors of an age-friendly city, which engages itself in volunteer and sociocultural activities recommended by the World Health Organization [40]. In Japan, after 2015, disability prevention focused on community development. This critical study suggests that increases in health-related SC, due to community development, may lead to decreases community-level depressive symptoms.

This research has three limitations. First, the target area of this study was 44 municipal units, which means that we could not verify the independence of each health-related SC, and there is a possibility that many factors could not be fully adjusted. However, we took advantage of the change between two time points, which may have controlled for time-invariant unobserved and observed confounding community characteristics [30].

Second, the use of repeated cross-sectional studies meant that we could not deny the possibility of reverse causality, such that increases in SC could have occurred as a result of decreases in depression. Other studies have demonstrated that the intervention promoting social participation in a community center increase health-related SC [16,17]. In Japan, the shift in the disability prevention measures allows the possibility that social participation in older adults is promoted by the increase in the number of places where older people can easily be active and participate, which can increase health-related SC.

6. Conclusions

We indicated that increases in municipality-level health-related SC factors, such as civic participation, social cohesion, and reciprocity, were related to decreases in municipality-level depressive symptoms using a 5-year repeated cross-sectional design, adjusting covariates. Our findings suggest that community SC interventions may reduce depressive symptoms in municipal units.

Supplementary Materials: The following are available online at http://www.mdpi.com/1660-4601/16/11/2038/s1, Table S1: Health-related social capital (SC) 5-year change by using sampling methods.

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Infrequent Denture Cleaning Increased the Risk of Pneumonia among Community-dwelling Older Adults: A Population-based Cross-sectional Study

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Pneumonia is a leading cause of death among older adults. The effectiveness of oral care in preventing pneumonia in nursing homes and hospitals has been reported. However, in community-dwelling older adults, the role of denture cleaning in preventing pneumonia remains unknown. We aimed to investigate the association between infrequent denture cleaning and the risk of pneumonia in community-dwelling older adults. This cross-sectional study was based on the self-reported questionnaire targeting towards community-dwelling older adults aged ≥65 years. Responses of 71,227 removable full/partial denture users were included. The incidence of pneumonia within the last one-year and the frequency of denture cleaning (daily/non-daily) were treated as dependent and independent variables, respectively. The odds ratio (OR) and 95% confidence interval (CI) were calculated by the inverse probability weighting (IPW) method based on the logistic regression model. The mean age of the participants was 75.2 ± 6.5 years; 48.3% were male. Overall, 4.6% of the participants did not clean their dentures daily; 2.3% and 3.0% who did and did not clean their dentures daily, respectively, experienced pneumonia. After IPW, infrequent denture cleaning was significantly associated with pneumonia incidence (OR = 1.30, 95% CI = 1.01–1.68)). This study suggests that denture cleaning could prevent pneumonia among community-dwelling older adults.

Pneumonia is a leading cause of hospitalization and death[1,2]. It is widely prevalent among the older population because of the decline in immune system and respiratory function with advancing age[3]. Aspiration is one of the mechanisms that explains the onset of pneumonia among older adults[4,5]. In fact, oral bacteria have been identified in the lungs of the patients who developed pneumonia; therefore, a relationship between aspiration of oral bacteria and pneumonia is strongly suggested[6]. In addition, because a substantial proportion of older adults are affected by dysphagia[7,8], the risk of pneumonia through aspiration may increase[4]. To reduce the risk of aspiration pneumonia, oral care has been implemented in nursing homes and has successfully decreased the incidence of pneumonia among the nursing home residents[9–11].

Although the role of oral care in reducing the risk of pneumonia has been recognized, the importance of denture cleaning has been relatively neglected. The presence of fewer or no teeth is prevalent among the older adults[12]; therefore, the use of removable dentures is a common treatment option. On the surface of the denture, a biofilm composed of microorganisms called "denture plaque" rapidly develops upon insertion after cleansing[13]. There is a possibility that the denture plaque may reach the lungs by aspiration, causing aspiration pneumonia. Although generally included as a part of oral care[11], previous studies have not focused on denture cleaning alone. In addition, most of the previous studies on the relationship between oral hygiene and pneumonia were carried

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out in nursing homes and hospitals[14,15]. However, the risk of aspiration pneumonia is considered to be high in community-dwelling older adults. To the best of our knowledge, no study has investigated the association between denture cleaning and pneumonia among community-dwelling older adults. From a public health viewpoint, as the majority of older adults are community-dwellers and not institutionalized, the prevention of pneumonia among community-dwelling older adults is important. In this study, we investigate whether infrequent denture cleaning is associated with the risk of developing pneumonia among community-dwelling older adults.

Methods

Settings and participants. This cross-sectional study is based on a self-reported questionnaire. The data were obtained from the survey of the 2016 Japan Gerontological Evaluation Study (JAGES). JAGES targeted the community-dwelling older adults aged ≥65 years, who were not certified to be eligible for long term public care. Information on social, behavioral, and health factors were collected. JAGES in 2016 was conducted in 39 municipalities in Japan. The questionnaire was sent by post and was retrieved by mail.

Dependent variable. We used the self-reported incidence of pneumonia within the last one-year as a dependent variable. We asked the question "*Did you experience the following diseases within the last one year?*" Those who answered "*pneumonia*" were considered to be the individuals who suffered from pneumonia within the last one year.

Independent variable. We used the frequency of denture cleaning as an independent variable. To those who used removable dentures, we asked the question "*Do you clean your dentures daily?*"; the choices provided were "*Yes*" or "*No*." We defined people chose "*Yes*" as those who cleaned their denture daily and "*No*" as those who cleaned their dentures infrequently (non-daily).

Covariates. We selected possible cofounders as covariates based on previous studies and clinical knowledge[1,16,17]; this included age, sex, smoking status, educational status, equivalent income, number of teeth, activities of daily living (ADL), comorbidity related to stroke or dementia, and experience of pneumococcal vaccination within last five-year.

Statistical analysis. We estimated the propensity score for the independent variable. The stabilized average treatment effect (ATE) on the risk of pneumonia was calculated using the inverse probability weighting (IPW) method. To predict the propensity score for infrequent denture cleaning, we used the logistic regression model; all the covariates were included as possible confounders and the stabilized ATE weight was calculated. The stabilized ATE weight was used to avoid instability of the estimated effect size due to extreme weighting[18]. We compared the standardized difference between the categories of independent variable before and after stabilized ATE weighting[19,20]. The standardized difference was used to check the balance of the covariates between the treated and control groups. If standardized difference of all covariates was <0.1 after weighting, it was regarded as well balanced. We developed the logistic regression model; the odds ratios (ORs) and 95% confidence intervals (95% CIs) were calculated using IPW with stabilized ATE weights (stabilized ATE-IPW). For missing responses, we presumed that the missing pattern of the original data set was missing at random. Multiple imputation by chained equation (MICE) was used to generate 20 imputed datasets. We calculated the stabilized ATE weighted OR for each data set and combined all estimators by Rubin's rule[21]. In the sensitivity analysis, the participants were stratified into two age groups (<75 or ≥75 years) for IPW. Then, the interaction effect of age and frequency of denture cleaning was confirmed by using the relative excess risk due to interaction (RERI) as additive scales and the ratio of OR as multiplicative scale between them[22]. We used Stata/MP version 15 (Stata Corp., College Station, TX, USA) for statistical analysis.

Ethical issue. In this study, the process of obtaining informed consent was as follows: the questionnaire was sent by mail along with the explanation of the study; the participants read the written explanation about the aim of study and replied. Hence, we considered that informed consent was provided by those who replied and sent back the questionnaire. The JAGES protocol in 2016 was approved by the ethics committee of National Center for Geriatrics and Gerontology (No. 992) and the ethics committee of Chiba University (No. 2493). We followed the STROBE Statement to report our observational study.

Results

From a target population of 279,661, 180,021 individuals participated in the survey (response rate = 70.2%). Of these, 88,994 (49.4%) participants who used removable dentures (including both removable full/partial dentures) were included in this analysis. However, 17,767 participants with missing information regarding the dependent variable were excluded. Finally, data of 71,227 participants were included in the analysis. Table 1 shows the characteristics of the participants. The mean age was 75.2 years (SD = 6.5); 48.3% were male. Overall, 2.3% (n = 1,666) and 97.7% (n = 69,561) of the participants, respectively, did and did not experience pneumonia within the last one year.

Table 2 shows the proportion of participants who experienced pneumonia based on the frequency of denture cleaning and stratified by age group. Pneumonia was more prevalent among the participants who did not clean their dentures daily, especially those aged ≥75 years. Among these participants aged ≥75 years, 2.9% and 4.3% of those who did and did not clean their dentures daily, respectively, experienced pneumonia.

To reduce the possibility of selection bias, we estimated the propensity score for denture cleaning after MICE. After multiple imputation, the missing values of 22,020 participants were imputed. The propensity scores were predicted using the logistic regression model separately for the entire data (all participants) and stratified data (participants aged <75 years or ≥75 years) for each imputed data sets. After using stabilized ATE weight, the

Characteristics	All participants (n = 71,227)		Experienced pneumonia within last one-year (n = 1,666)		Not experienced pneumonia within last one-year (n = 69,561)	
	n	%	n	%	n	%
Frequency of denture cleaning						
Daily	67,208	94.4	1,547	92.9	65,661	94.4
Non-daily	3,293	4.6	100	6.0	3,193	4.6
Missing	726	1.0	19	1.1	707	1.0
Age						
65–69 years	16,770	23.5	248	14.9	16,522	23.8
70–74 years	18,579	26.1	365	21.9	18,214	26.2
75–79 years	17,347	24.4	425	25.5	16,922	24.3
80–84 years	11,858	16.6	369	22.2	11,489	16.5
≥85 years	6,673	9.4	259	15.6	6,414	9.2
Sex						
Male	34,393	48.3	984	59.1	33,409	48.0
Female	36,825	51.7	682	40.9	36,143	52.0
Missing	9	0.0	0	0.0	9	0.0
Education						
≤9 years	25,133	35.3	706	42.4	24,427	35.1
10–12 years	28,513	40.0	596	35.8	27,917	40.1
≥13 years	16,611	23.3	331	19.9	16,280	23.4
Missing	970	1.4	33	2.0	937	1.4
Equivalent income (100 JPY ≈ 1 USD)						
<1,000,000 JPY	7,568	10.6	230	13.8	7,338	10.6
1,000,0000–1,999,999 JPY	21,017	29.5	455	27.3	20,562	29.6
2,000,0000–2,999,999 JPY	13,401	18.8	274	16.5	13,127	18.9
3,000,0000–3,999,999 JPY	8,055	11.3	124	7.4	7,931	11.4
≥4,000,000 JPY	5,701	8.0	117	7.0	5,584	8.0
Missing	15,485	21.8	466	28.0	15,019	21.6
Smoking status						
Never	39,027	54.8	702	42.2	38,325	55.1
Quite	22,368	31.4	772	46.3	21,596	31.1
Current	8,726	12.3	145	8.7	8,581	12.3
Missing	1,106	1.5	47	2.8	1,059	1.5
Dementia						
Yes	484	0.7	16	1.0	468	0.7
No	68,468	96.1	1,620	97.2	66,848	96.1
Missing	2,275	3.2	30	1.8	2,245	3.2
Stroke						
Yes	2,197	3.1	76	4.6	2,121	3.1
No	66,755	93.7	1,560	93.6	65,195	93.7
Missing	2,275	3.2	30	1.8	2,245	3.2
Activities of daily living						
No need for personal assistance	63,052	88.5	1,300	78.0	61,752	88.8
Require some personal assistance	4,787	6.7	255	15.3	4,532	6.5
Missing	3,388	4.8	111	6.7	3,277	4.7
Number of teeth						
0	10,620	14.9	337	20.2	10,283	14.8
1–4	7,577	10.6	217	13.0	7,360	10.6
5–9	11,707	16.4	299	18.0	11,408	16.4
10–19	20,687	29.1	437	26.2	20,250	29.1
≥20	19,096	26.8	320	19.2	18,776	27.0
Missing	1,540	2.2	56	3.4	1,484	2.1
Experience of pneumococcal vaccination within last five-year						
Yes	30,174	42.4	1,016	61.0	29,158	41.9
No	39,349	55.2	565	33.9	38,784	55.8
Missing	1,704	2.4	85	5.1	1,619	2.3

Table 1. Characteristics of the participants (n = 71,227).

n (%)	All participants (n = 70,501)		65–74 years (n = 35,062)		≥75 years (n = 35,439)	
	Frequency of denture cleaning		Frequency of denture cleaning		Frequency of denture cleaning	
	Daily	Non-daily	Daily	Non-daily	Daily	Non-daily
Incidence of pneumonia within the last one year						
Yes	1,547 (2.3)	100 (3.0)	575 (1.7)	34 (1.9)	972 (2.9)	66 (4.3)
No	65,661 (97.7)	3,193 (97.0)	32,733 (98.3)	1,720 (98.1)	32,928 (97.1)	1,473 (95.7)

Table 2. The incidence of pneumonia within the last one year based on the frequency of denture cleaning stratified by age groups.

Frequency of denture cleaning	All participants (n = 71,227)	65–74 years (n = 35,349)	≥75 y (n = 35,878)
	Stabilized ATE weighted	Stabilized ATE weighted	Stabilized ATE weighted
	OR (95% CI)	OR (95% CI)	OR (95% CI)
Daily	Ref.	Ref.	Ref.
Non-daily	1.30 (1.01–1.68)	0.98 (0.64–1.50)	1.58 (1.15–2.17)

Table 3. The association between the incidence of pneumonia within the last one year and the frequency of denture cleaning. *Note:* ATE = average treatment effect, OR = odds ratio, 95%CI = 95% confidence interval, Ref. = reference.

standardized differences of all covariates were <0.1 (Supplementary Table 1). Therefore, by using the estimated propensity score, we confirmed that the all the covariates are well balanced between those who did and did not cleaned their dentures daily. Table 3 shows the results of the logistic regression analysis using the stabilized ATE-IPW method; infrequent denture cleaning was significantly associated with the incidence of pneumonia among all participants (OR = 1.30, 95% CI = 1.01–1.68). In addition, the sensitivity analysis based on stratification by age groups showed that infrequent denture cleaning was significantly associated with the occurrence of pneumonia among those aged ≥75 years (OR = 1.58, 95% CI = 1.15–2.17). In contrast, a significant association between infrequent denture cleaning and the incidence of pneumonia was not observed among those aged <75 years (OR = 0.98, 95% CI = 0.64–1.50). However, the additive and multiplicative scale of interaction effect was not significant (Supplementary Table 2).

Discussion

The present study revealed that infrequent denture cleaning was associated with the incidence of pneumonia within the last one year among community-dwelling older adults. This result suggests the importance of denture cleaning in reducing the risk of pneumonia among community-dwelling older adults. From the public health viewpoint, this is an important finding because the number of community-dwelling older adults is increasing in this aging world.

As mentioned in the introduction, previous studies suggested that oral hygiene including denture cleaning was associated with the incidence of pneumonia among nursing homes residents[11]; the present study showed a similar association among the community-dwelling older adults. A study conducted in nursing home reported a reduction of death due to pneumonia among older residents by oral care including denture cleaning[23]. We added that frequent denture care could reduce the incidence of pneumonia in community-dwelling older adults.

Denture plaque is composed from many species of bacteria and fungus; some of them are regarded as pathogen of pneumonia[24,25]. Infrequent denture cleaning causes accumulation of denture plaque[26], and therefore, the possibility of the pathogens reaching the lung by aspiration might increase[27]. Consequently, it may be presumed that the pathogens from denture plaque accumulated due to infrequent cleaning were aspirated and may have increased the risk of pneumonia. In the present analysis, a strong association was observed among those aged ≥75 years, although a statistical significance was not clearly observed. With advancing age, the immune system declines[3] and aspiration is more likely to occur in older adults rather than those who are younger[28]. The mortality rate of pneumonia is increasing among the older adults[2]. Therefore, the results of the present study are reasonable: those aged ≥75 years were more likely to develop pneumonia and the harmful effect of infrequent denture cleaning was stronger than that observed in younger participants. These results are supported by the biological explanations mentioned above. Further study considering the effect modification of dysphagia on the association between poor oral hygiene and pneumonia incidence would strengthen our explanation of the results of the present study.

The strength of this study was the inclusion of over 70,000 participants; this sample size was large enough to detect the association between infrequent denture cleaning and pneumonia. The incidence of pneumonia among community-dwelling older adults is lower than that in nursing homes where frail older adults live[29]. Therefore, it is difficult to have sufficient statistical power to detect the association in smaller epidemiological studies. This study, however, has several limitations. As this was a cross-sectional study, we could not evaluate the causal relationship between denture cleaning and pneumonia. However, it is less likely that the occurrence of pneumonia would lead to infrequent denture cleaning. In addition, the self-reported incidence of pneumonia causes reporting bias. However, the incidence of pneumonia in this study is similar to that previously reported[30]. Therefore, the reporting bias caused by the self-reporting of pneumonia was considered to be relatively small.

The self-reported independent variable, denture cleaning, also created bias. A wide variety of denture cleaning methods and techniques may be used by the participants. Our questionnaire could not obtain information on the details regarding the denture cleaning methods. However, this reporting bias could widen the 95% confidence interval of our estimates. Despite this situation, there was a significant association of denture cleaning with pneumonia; therefore, we consider the present results to be robust. Furthermore, those who died because of pneumonia were not included in this study. This selection bias is considered to cause an underestimation of the association between denture cleaning and pneumonia. In the present results, the benefit of denture cleaning was remarkable among only older adults aged ≥75 years. The individuals who died from pneumonia are considered to be frail and very old[27,29]; therefore, the impact of denture cleaning on these individuals is larger than those who experienced pneumonia but are alive. The previous study revealed an association between denture wearing during sleep and pneumonia incidence among community-dwelling older adults[31]. The results of this previous study were similar to those from our study. There was a possibility of multicollinearity between denture wearing during sleep and infrequent denture cleaning. In our survey, a question about denture wearing during sleep was asked to only one-eighth of all participants (n = 8,316), so we did not include this variable in the present analysis to avoid decreasing the sample size. When analyzing this variable alone, we confirmed that the proportions of those wearing dentures during sleep were similar among those participants who did/did not clean their dentures daily (17.3% among those who cleaned their dentures daily and 18.5% among those who did not clean their dentures daily wore dentures during sleep; chi-square test, $p = 0.544$). Therefore, infrequent denture cleaning is associated with pneumonia incidence and is independent of denture wearing during sleep.

Conclusion

The present study revealed that infrequent denture cleaning was associated with the incidence of pneumonia within the last one year among community-dwelling older adults. Daily cleaning of dentures may reduce the risk of pneumonia among community-dwelling older adults. In the chair side, dental professionals need to instruct their patients to keep their dentures clean to prevent pneumonia. Even for community-dwelling older adults, dental professionals should pay more attention to oral hygiene for pneumonia prevention.

Data Availability

All data needed to evaluate the conclusions in the paper are present in the paper and/or the Supplementary Materials. The JAGES data used in this study will be made available upon request. The authors require the applicant to submit an analysis proposal to be reviewed by an internal JAGES committee to avoid duplication. Confidentiality concerns prevent us from depositing our data in a public repository. Proposals submitted by outside investigators will be discussed during the monthly investigators' meeting to ensure that there is no overlap with ongoing analyses. If approval to access the data is granted, the JAGES researchers will request the outside investigator to help financially support our data manager's time to prepare the data for outside use.

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Author Contributions

T.K.: conception and design. J.A.: conception and design, acquisition of data. T.Y., K.K., K.O.: acquisition of data. All authors: analysis and interpretation of data, drafting the article, critical revision and approval of final manuscript.

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RESEARCH ARTICLE

Socio‐economic status and dementia onset among older Japanese: A 6‐year prospective cohort study from the Japan Gerontological Evaluation Study

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Abstract

Objectives

Lower socio‐economic status (SES) may be associated with dementia later in life, but there is inconsistent evidence supporting this claim. We aim to examine the association between three SESs (education, job, and income indicators) and dementia onset in older adults.

Methods

Study design was a 6‐year prospective cohort study. Participants included a total of 52 063 community‐dwelling adults aged 65 years or older without long‐term care needs from the Japan Gerontological Evaluation Study. Outcome variable was dementia onset. Explanatory variables were educational years, the longest job held, and equivalised household income. We performed Cox proportional hazard analysis by gender with multiple imputation.

Results

During the follow‐up period, 10.5% of participants acquired dementia. The adjusted risks of dementia incidence of the participants with less than 6 years of education were 1.34 times (95% confidence interval [CI], 1.04‐1.73) in men and 1.21 (1.00‐1.45) times in women higher than those with more than 13 years of education. Females with less than 1.99 million yen (hazard ratio = 0.83, 0.72‐0.96) of equivalised income were less likely to acquire dementia than those with four million yen or higher.

Conclusions

Educational attainment had a robust impact on dementia onset compared with the other SES factors in both genders of older Japanese people. Securing an education for children could be crucial to prevent dementia later in life. The longest job held was less likely to be risks of dementia incidence, compared with the other two factors.

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Socioeconomic Disparity in the Prevalence of Objectively Evaluated Diabetes Among Older Japanese Adults: JAGES Cross-Sectional Data in 2010

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ABSTRACT

Background: Studies on sex-specific socioeconomic gradients in objectively evaluated diabetes among older adults are scarce.

Methods: We used cross-sectional data of 9,893 adults aged 65 years and older in Aichi Prefecture without long-term care insurance from the Japan Gerontological Evaluation Study (JAGES) in 2010 (Response rate: 66.3%). We collected demographic, socioeconomic (income, years of education, and longest occupation) and behavioral information using a mail-in self-reported survey. Blood samples for the objectively evaluated diabetes and self-reported medical history were collected at annual municipal health checkups. Poisson regression analysis stratified by sex with multiple imputations was conducted to calculate prevalence ratio and 95% confidence interval.

Results: A clear income gradient in diabetes prevalence was observed among women, from 11.7% in the lowest income quartile (Q1) to 7.8% in the highest (Q4). Among men, the findings were 17.6% in Q1 to 15.1% in Q4. The prevalence ratios for diabetes with incomes Q1 to Q4 were 1.43 (95% confidence interval [CI], 1.07–1.90) for women and 1.16 (95% CI, 0.90–1.50) for men after adjusting for age and other socioeconomic factors. Even after adjusting for marital status, body mass index, other metabolic risk factors, and lifestyle factors, the income-based gradient remained among women. Education and occupation were not significantly associated with diabetes in the study population.

Conclusions: Only women showed an income-based gradient in diabetes. Monitoring income gradient in diabetes is important in public health actions, even in older populations. Future longitudinal and intervention studies should evaluate the causal link of income to diabetes onset, determine the mechanisms of the potential sex differences in the income/diabetes association, and identify ways to mitigate the income-based inequality.

Key words: socioeconomic status; diabetes mellitus; sex differences; elderly adults; Japan

INTRODUCTION

According to global reports on diabetes 2016, about 422 million adults were living with diabetes worldwide in 2014. During the past 4 decades, the global prevalence of adult diabetes has nearly doubled, increasing from 4.7% to 8.5%.[1] In Japan, the National Health and Nutrition Survey reported that 16.2% of men and 9.2% of women aged over 20 years were suspected to have diabetes in 2015.[1] About 3.2 million people (1.8 million men and 1.4 million women) received treatment for diabetes in 2014,[2] and 70% were over 65 years old.

Socioeconomic disparities in diabetes prevalence and incidence have been well documented in Western countries[3–11] and some Asian countries, including South Korea,[12] China,[13,14] Taiwan,[15] and Japan.[16,17] Except for one study in China,[14] inverse relationships between socioeconomic status (SES) and diabetes prevalence or incidence have been observed according to occupational class,[3,18,19] income level,[10,18,20] and educational attainment.[3,10,18–22] However, few studies have investigated the social gradient in diabetes among older adults, and the findings of studies using data among older populations have been inconsistent with respect to the association between SES and

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diabetes. For example, a Finnish study has shown that the low-income group had a higher diabetes prevalence compared with the high-income group among women, whereas among men the high-income group was more likely to have diabetes.[6] Studies in Germany[23] and the United Kingdom[5] have shown that neither income, education, nor occupation was associated with the incidence of diabetes.

To date, many studies have suggested sex differences in the association between SES and diabetes. Most studies have reported more obvious social gradients in diabetes among women than men in Western countries.[3,6,18–20,22] In Asian countries, only Lee et al in South Korea investigated sex differences in the association between SES and diabetes, similarly showing a stronger SES-diabetes association among women than men.[21] No evidence of sex differences in the association between SES and diabetes has been reported from other parts of Asia, including Japan.

These studies, other than the study in the United Kingdom ($N = 7,432$), are not large (Finland: $N = 379$, Germany $N = 1,223$), which may be a limitation in detecting the between-group gaps. Moreover, in the recent studies, the definitions of diabetes vary. For example, diabetes was defined using self-reports,[6] first diabetes medication prescribed,[5] and oral glucose tolerance tests.[23] Specifically, self-report of having diabetes could induce reporting bias. The validity study by Goto et al found that positive predictive value of self-report diabetes was 75.7%, whereas negative predictive value was 96.5% in the Japanese population.[24] The bias may go toward null on the association between SES and diabetes prevalence, given that health-conscious people with high health literacy recognize their health status more accurately. According to a Japanese nationally representative survey, health-conscious people are likely to be more educated.[25] To our knowledge, no studies have investigated the association between objectively diagnosed diabetes and SES among the older population.

Therefore, the purpose of this study was to investigate (1) whether there is an association between SES and diabetes prevalence among Japanese older adults, and (2) whether there is a sex difference in this association, using large-scale cross-sectional data with objectively measured biomarkers of diabetes.

METHODS

Study participants

We used cross-sectional data of the 2010 wave of the Japan Gerontological Evaluation Study (JAGES). In 2010, in JAGES we sent the questionnaires to 169,215 community-dwelling individuals over 65 years without long-term care insurance. From 31 municipalities in 12 out of 47 prefectures throughout Japan, participants were randomly selected from the public residence registries in 15 large municipalities; in the 16 smaller municipalities, all eligible residents got the mail-in survey. In total 112,123 subjects answered the questionnaire (response rate: 66.3%). After excluding the individuals with missing in demographic characteristics, 102,869 subjects were valid for analysis. Since JAGES exclude long-term care insurance takers from the study participants, we cannot compare the characteristics of the participants with the national census directly. However, the sex ratio of the total JAGES 2010 individuals was mostly comparable to that of the national census (national census: 42.6% men, 57.4% women; JAGES2010 data: 45.9% men, 54.1% women). JAGES female population was younger than that of the national census (national census: 32.2% age group ≥80; JAGES2010: 21.5% age group ≥80), whereas the age structure of the male population was mostly identical.[26]

In addition to these data, we obtained data of 9,893 JAGES participants with results of annual health checkups from five municipalities in Aichi Prefecture that participated in JAGES. After excluding participants with data missing for HbA1c, fasting blood glucose, casual blood glucose, or information of medication ($N = 306$) or SES variables (income, education and longest occupation) ($N = 2,774$), a total 6,813 (3,475 men and 3,338 women) participants were eligible for the analysis. We applied multiple imputation methods for the individuals having one or more missing data. Thus, the final study sample was 9,893 (4,471 men and 5,422 women). Approvals were received by the Ethics Committee in Research of Human Subjects at Nihon Fukushi University for the JAGES protocol (No. 10-05) and by the Ethics Committee of Chiba University, Faculty of Medicine for the use of the data (No. 1777).

Measurement of diabetes and other metabolic risk factors

Annual health checkups are organized by local municipalities of Japan and performed at community centers or registered clinics or hospitals. Participant blood samples taken at annual checkups were analyzed following the standardized procedure of the Japan Society of Clinical Chemistry for HbA1c, fasting glucose, casual glucose, triglycerides (TG), and high-density lipoprotein (HDL) cholesterol. The HbA1c ratios were reported as the Japan Diabetes Society (JDS) values, then calculated for the values of the National Glycohemoglobin Standardization Program (NGSP) following a conversion formula.[27] Blood pressure was measured twice in the right upper arm with participants in the sitting position, and the mean of the two measurements was recorded.

Definition of diabetes and other metabolic risk factors

Based on the report from the Committee of the JDS on the Diagnostic Criteria of Diabetes Mellitus,[28] we defined diabetes mellitus as having HbA1c of over 6.5% based on the NGSP and fasting blood sugar ≥126 mg/dL (≥7.0 mmol/L) and/or casual blood sugar ≥200 mg/dL (≥11.1 mmol/L). People regularly taking hypoglycemic agents or insulin were also considered to have diabetes. We used the following criteria of the Japanese Society of Internal Medicine[29] to define other metabolic risks: hypertriglyceridemia (TG ≥150 mg/dL), low HDL cholesterol (HDL <40 mg/dL), or taking appropriate medication and hypertension (systolic blood pressure ≥140 mm Hg and/or diastolic blood pressure ≥90 mm Hg or taking antihypertensive drugs).

Socioeconomic status

Information of participants' annual household income, educational attainment, and longest occupation were collected using JAGES questionnaires. To adjust for differences in household size, we equivalized household income to per person in a household, dividing annual household income by the square root of the number of individuals per household. Because the income level of the participants was slightly higher than that of the entire JAGES population in 2010 (eTable 1), to apply the income level of the entire JAGES population, we categorized the study participants using quartiles of equivalized household income of all JAGES 2010 participants. We categorized the individuals into

four groups: Q1 (low), JPY 1.25 million per year and below; Q2 (lower middle), JPY 1.251–1.944 million per year; Q3 (upper middle), JPY 1.945–3.061 million per year and Q4 (high), JPY 3.062 million per year and above. Educational status was categorized by the number of years of schooling (9 years or fewer, 10–12 years, and 13 years or more). Longest occupation was queried as follows: "What was the job that you did for most of your working life?" Responses included the following eight options: professional/technical, managerial, clerical, sales/service, skilled/manual, agriculture/forestry/fishery workers, other, and unemployed.[30]

Covariates

We used categorical 5-year age groups, marital status, body mass index (BMI), other metabolic risks defined above, current smoking, current alcohol intake, physical activities, and dietary intake habits as covariates; these factors could be mediators of the association between SES and diabetes. Marital status was categorized as married, widowed, separated/unmarried, and other. BMI was classified into four groups: BMI <18.5, 18.5–24.9, 25.0–29.9, and ≥30.0. Other lifestyle factors included smoking status (nonsmoker or current smoker/ex-smoker), alcohol intake (nondrinker or drinker/ex-drinker), and walking time per day as physical activity (<30 min or ≥30 min). As for dietary intake habits, we included frequencies of the consumption of meat or fish (<1 servings/day or ≥1 servings/day) and fruit or vegetables (<1 servings/day or ≥1 servings/day).

Statistical analysis

First, we calculated the prevalence of diabetes by the levels of socioeconomic indicators. Chi-squared test for sex was performed both in Table 1 and Table 2. Second, we performed multivariate Poisson regression analysis to calculate prevalence ratios (PRs) of diabetes and their 95% confidence intervals (CIs) across SES groups. To account for the potential biases due to the missing values, we used the multiple imputation techniques. All variables included in the analysis, such as the outcome variable, diabetes, explanatory variables, and covariates were imputed. Under a missing-at-random assumption, we created 10 imputed data using chained equation method, made analyses for each dataset, and combined the 10 results, using Rubin's combination method.[31,32] Under the chained equation method, we performed multinomial logistic regression for the categorical variables and ordinal logistic regression for the ordinal variables. We treated occupation and marital status as nominal variables and categorized diabetes, income, education, BMI, hypertension, triglyceridemia, smoking habit, alcohol intake, walking duration per day, and eating habit as ordinal variables, including dichotomous variables. Model 1 was adjusted for age and each SES indicators (income quartile, years of education, and longest occupation) separately. Model 2 was adjusted for age and all SES indicators. Model 3 was additionally adjusted for marital status, BMI, hypertension, low HDL, high TG, smoking status, alcohol intake, walking time per day, meat/fish intake, and fruit/vegetable intake.

Preliminary analysis showed that the interaction terms for sex and socioeconomic indicators were not statistically significant (*P*-value for the interaction term between income and sex = 0.18, *P*-value for the interaction term between education and sex = 0.20). However, as Hawkes et al mentioned,[33] irrespective of the statistical significance, the gender-stratified analysis is essential to address the determinants of ill health by gender. Accordingly, we decided to analyze the data stratified by sex. Also, to investigate the validity of our missing-at-random assumption for multiple imputations, we conducted a sensitivity analysis using the complete case dataset (eTable 2). We used Stata/SE version 13.1 (StataCorp LLC, College Station, TX, USA) for the analyses.

Table 1. Participant characteristics (*N* = 6,813)

		Men	Women	
		(*N* = 3,475)	(*N* = 3,338)	*P*-value[a]
Diabetes	No	2,948 (84.8%)	2,996 (89.8%)	<0.001
	Yes	527 (15.2%)	342 (10.2%)	
Age, years	65–69	1,297 (37.3%)	1,335 (40.0%)	0.13
	70–74	1,213 (34.9%)	1,093 (32.7%)	
	75–79	606 (17.4%)	572 (17.1%)	
	80 and above	359 (10.3%)	338 (10.1%)	
Income quartile[b]	Q1	534 (15.4%)	795 (23.8%)	<0.001
	Q2	1,091 (31.4%)	903 (27.1%)	
	Q3	1,054 (30.3%)	897 (26.9%)	
	Q4	796 (22.9%)	743 (22.3%)	
Years of education	9 or less	1,556 (44.8%)	1,715 (51.4%)	<0.001
	10–12	1,284 (36.9%)	1,259 (37.7%)	
	13 and over	635 (18.3%)	364 (10.9%)	
Longest occupation	Professional/technical	968 (27.9%)	351 (10.5%)	<0.001
	Managerial	345 (9.9%)	26 (0.8%)	
	Clerical	371 (10.7%)	812 (24.3%)	
	Sales/service	309 (8.9%)	646 (19.4%)	
	Skilled/manual	970 (27.9%)	413 (12.4%)	
	Agriculture/forestry/fishery worker	202 (5.8%)	217 (6.5%)	
	Other	303 (8.7%)	572 (17.1%)	
	Unemployed	7 (0.2%)	301 (9.0%)	
Marital status	Married	3,159 (90.9%)	2,329 (69.8%)	<0.001
	Widowed	227 (6.5%)	861 (25.8%)	
	Separated/unmarried	65 (1.9%)	123 (3.7%)	
	Other/missing	24 (0.7%)	25 (0.7%)	
BMI, kg/m^2	<18.5	77 (2.2%)	160 (4.8%)	<0.001
	18.5–24.9	1,671 (48.1%)	1,539 (46.1%)	
	25.0–29.9	573 (16.5%)	449 (13.5%)	
	≥30.0	36 (1.0%)	67 (2.0%)	
	Missing	1,118 (32.2%)	1,123 (33.6%)	
Hypertension	No	1,500 (43.2%)	1,406 (42.1%)	0.040
	Yes	1,659 (47.7%)	1,675 (50.2%)	
	Missing	316 (9.1%)	257 (7.7%)	
High TG	No	2,208 (63.5%)	2,145 (64.3%)	0.54
	Yes	1,267 (36.5%)	1,193 (35.7%)	
Low HDL	No	2,682 (77.2%)	2,673 (80.1%)	0.004
	Yes	793 (22.8%)	665 (19.9%)	
Smoking status	No	824 (23.7%)	2,851 (85.4%)	<0.001
	Smoker/ex-smoker	2,433 (70.0%)	192 (5.8%)	
	Missing	218 (6.3%)	295 (8.8%)	
Alcohol intake	Drinker/ex-drinker	2,248 (64.7%)	631 (18.9%)	<0.001
	None	1,036 (29.8%)	2,543 (76.2%)	
	Missing	191 (5.5%)	164 (4.9%)	
Walking time, min/day	<30	889 (25.6%)	989 (29.6%)	<0.001
	≥30.0	2,447 (70.4%)	2,183 (65.4%)	
	Missing	139 (4.0%)	166 (5.0%)	
Meat/fish intake, servings/day	≥1	1,138 (32.7%)	1,376 (41.2%)	<0.001
	<1	2,133 (61.4%)	1,796 (53.8%)	
	Missing	204 (5.9%)	166 (5.0%)	
Fruit/vegetable intake, servings/day	≥1	2,478 (71.3%)	2,773 (83.1%)	<0.001
	<1	812 (23.4%)	406 (12.2%)	
	Missing	185 (5.3%)	159 (4.8%)	

BMI, body mass index; HDL, high-density lipoprotein; TG, triglyceride.
[a]Chi-squared test for sex.
[b]Income quartile calculated by all participants in JAGES2010 ('Low' −1.250, 'Middle-low' 1.251–1.944, 'Middle-high' 1.945–3.061, 'High' 3.062− million yen per year).

RESULTS

Among our study participants, 15.2% of men and 10.2% of women had diabetes. Around 70% of both men and women were

Table 2. Prevalence of diabetes mellitus by socioeconomic status and sex ($N = 6,813$)

	N	Men	*N*	Women
Income quartile[a]				
Q1	534	94 (17.6%)	795	93 (11.7%)
Q2	1,091	147 (13.5%)	903	105 (11.6%)
Q3	1,054	166 (15.7%)	897	86 (9.6%)
Q4	796	120 (15.1%)	743	58 (7.8%)
P-value		0.16		0.03
Years of formal education				
9 or less	1,556	237 (15.2%)	1,715	187 (10.9%)
10–12	1,284	196 (15.3%)	1,259	113 (9.0%)
13 and over	635	94 (14.8%)	364	42 (11.5%)
P-value		0.96		0.16
Longest occupation				
Professional/technical	968	145 (15.0%)	351	43 (12.3%)
Managerial	345	56 (16.2%)	26	5 (19.2%)
Clerical	371	59 (15.9%)	812	71 (8.7%)
Sales/service	309	51 (16.5%)	646	55 (8.5%)
Skilled/manual	970	132 (13.6%)	413	47 (11.4%)
Agriculture/forestry/fishery workers	202	28 (13.9%)	217	21 (9.7%)
Other	303	53 (17.5%)	572	62 (10.8%)
Unemployed	7	3 (42.9%)	301	38 (12.6%)

P-values were calculated using Chi-squared test.
[a]Income quartile calculated by all participants in JAGES2010 ('Low' –1.250, 'Middle-low' 1.251–1.944, 'Middle-high' 1.945–3.061, 'High' 3.062– million yen per year).

under 75 years old (Table 1). A total 15.4% of men and 23.8% of women were in the low-income quartile; these percentages were 22.9% and 22.3%, respectively, for the high-income quartile. With regard to years of formal education, 44.8% of men and 51.4% of women had nine years or fewer years of schooling, and 18.3% of men and 10.9% of women had 13 years or more. Distributions of longest occupation were entirely different between men and women. Compared with the entire JAGES 2010 population, our study participants were older; had slightly higher income and lower education levels; and there were more married and physically active participants, as well as more alcohol drinkers (eTable 1).

The prevalence of diabetes by income quartile among men was 17.6% in Q1 (lowest income), 13.5% in Q2, 15.7% in Q3, and 15.1% in Q4 (highest income) ($P = 0.16$); among women, prevalence values were 11.7% in Q1, 11.6% in Q2, 9.6% in Q3, and 7.8% in Q4 ($P = 0.03$) (Table 2). Education- and occupation-related gradients were not observed in the population.

The results of multivariate analysis showed that among women, an income-based gradient was observed in the prevalence of diabetes. Compared with Q4 (highest income category), PRs of diabetes for Q1, Q2, and Q3 were 1.43 (95% CI, 1.07–1.90), 1.33 (95% CI, 1.01–1.75), and 1.22 (95% CI, 0.91–1.64) (*P* for trend = 0.01; Table 3, women, model 1). After mutually adjusting for each SES factor, the PRs of Q1, Q2, and Q3 compared to Q4 were 1.42 (95% CI, 1.06–1.90), 1.33 (95% CI, 1.00–1.76), and 1.23 (95% CI, 0.91–1.65), respectively (*P* for trend = 0.016; Table 3, women, model 2). Even after adjustment for marital status, BMI, other metabolic risk factors, and lifestyle factors, the association was not attenuated (Q1: PR 1.43; 95% CI, 1.07–1.92, Q2: PR 1.32; 95% CI, 0.99–1.76; Q3: PR 1.22; 95% CI, 0.91–1.65; *P* for trend = 0.01; Table 3, women, model 3). No socioeconomic gradient was observed among men (Table 3).

The estimates based on our sensitivity analysis using complete case data were mostly identical to our original analysis with slightly smaller PRs and wider CIs (eTable 2).

DISCUSSION

Using the large-scale data of Japanese older adults, we found two major findings on the social inequality in objectively measured

Table 3. Prevalence ratios and 95% confidence intervals for diabetes mellitus by sex with multiple imputation ($N = 9,893$)

	Men ($N = 4,471$)			Women ($N = 5,422$)		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Income quartile						
Q1 (lowest)	1.16 (0.90–1.50)	1.16 (0.88–1.52)	1.18 (0.89–1.56)	1.43 (1.07–1.90)	**1.42 (1.06–1.90)**	**1.43 (1.07–1.92)**
Q2	0.93 (0.74–1.17)	0.94 (0.74–1.19)	0.96 (0.76–1.22)	1.33 (1.01–1.75)	**1.33 (1.00–1.76)**	**1.32 (0.99–1.76)**
Q3	1.02 (0.79–1.30)	1.03 (0.80–1.32)	1.02 (0.80–1.31)	1.22 (0.91–1.64)	1.23 (0.91–1.65)	1.22 (0.91–1.65)
Q4 (Highest)	1 (referent)	1 (referent)	1 (referent)	1 (referent)	1 (referent)	1 (referent)
Trend *P*	0.52	0.55	0.44	**0.01**	**0.016**	**0.01**
Years of formal education						
9 years or less	0.97 (0.78–1.20)	0.99 (0.78–1.24)	1.01 (0.80–1.27)	1.03 (0.77–1.39)	0.97 (0.72–1.33)	0.94 (0.69–1.28)
10–12	1.00 (0.81–1.25)	1.02 (0.81–1.27)	1.02 (0.81–1.27)	0.96 (0.71–1.30)	0.96 (0.71–1.31)	0.95 (0.69–1.29)
13+	1 (referent)	1 (referent)	1 (referent)	1 (referent)	1 (referent)	1 (referent)
Trend *P*	0.701	0.84	0.99	0.56	0.96	0.72
Longest occupation						
Professional/Technical	1 (referent)	1 (referent)	1 (referent)	1 (referent)	1 (referent)	1 (referent)
Managerial	0.98 (0.73–1.32)	0.98 (0.73–1.33)	0.98 (0.73–1.33)	1.20 (0.60–2.41)	1.21 (0.60–2.41)	1.20 (0.60–2.40)
Clerical	1.03 (0.77–1.38)	1.03 (0.77–1.38)	1.05 (0.78–1.42)	0.84 (0.59–1.20)	0.86 (0.60–1.24)	0.88 (0.62–1.26)
Sales/Service	1.05 (0.79–1.41)	1.04 (0.78–1.39)	1.01 (0.75–1.35)	0.79 (0.55–1.12)	0.77 (0.53–1.10)	0.75 (0.53–1.08)
Skilled/Manual	0.86 (0.69–1.08)	0.87 (0.69–1.09)	0.86 (0.68–1.08)	0.99 (0.69–1.43)	0.97 (0.66–1.41)	0.95 (0.65–1.39)
Agriculture/Forestry/Fishery workers	0.91 (0.63–1.31)	0.89 (0.62–1.30)	0.88 (0.61–1.29)	0.86 (0.55–1.33)	0.83 (0.53–1.29)	0.81 (0.52–1.27)
Others	1.12 (0.84–1.48)	1.10 (0.82–1.47)	1.08 (0.81–1.45)	1.03 (0.72–1.46)	0.99 (0.69–1.42)	0.98 (0.68–1.41)
Unemployed	1.64 (0.68–3.94)	1.60 (0.66–3.90)	1.59 (0.66–3.86)	1.03 (0.68–1.57)	1.00 (0.65–1.54)	0.98 (0.64–1.50)

Model 1 was adjusted for adjusted for income quartile, years of formal education and longest occupation separately with age.
Model 2 was adjusted for income quartile, years of formal education, longest occupation, and age.
Model 3 was additionally adjusted for marital status, BMI, hypertension, low HDL, high TG, smoking status, alcohol drinking habit, walking time per day, and meat/fish intake and vegetable intake.

diabetes: 1) the clear income gradient in diabetes prevalence was only observed among women but not among men; and 2) among men and women, there was no clear gradient in diabetes prevalence by years of education and longest occupation.

The socioeconomic gradient was potentially more marked among women, which was consistent with recent studies in other countries.[12,21] Robbins et al have proposed, as potential reasons, that women culturally have difficulties in health care access than men, fewer opportunities for regular exercise, unhealthy lifestyle behaviors, disadvantaged nutritional factors, more psychological stress, more depression, and more negative pre- or peri-natal environmental factors.[18] Other scholars have suggested the different roles of obesity in the association between income and diabetes by sex. In a Swedish study, Agardh et al found that among the low-income group, BMI explained their excess risk for subjectively diagnosed type 2 diabetes by 21% among men and 35% among women.[3] Nonetheless, a study from Canada that investigated the association between self-reported diabetes and SES found that BMI did not explain the associations between income and diabetes both among men and women.[20] In the present study, further adjustment for covariates, including BMI, did not substantially alter the association between income and diabetes for both sexes. To clarify the reasons for the sex difference, further studies are needed.

We found a gradient in diabetes by income but not by education or occupation. In theory, income has both materialistic and psychosocial functions, and they may explain the income gradient in diabetes distinctively. First, low income means limited access to material goods and services to prevent diabetes, such as balanced diet and necessary preventive care.[34] Second, the access limitation also leads to the social isolation and exclusion because of the lack of opportunities for social interactions, leading to mental stresses. Stress science and endocrinological studies have suggested the direct effects of stress hormones on blood glucose levels and insulin intolerance, as well as health behaviors.[34] Potential gender differences in our result could be explained by the psychosocial functions of income, including health beliefs, attitudes, and lifestyles, which may differ between men and women even at the same income levels.[21] Specifically, as suggested by Saito et al, the loss of social interactions due to the lack of income might affect women more than men among Japanese older adults.[35] Lastly, although the detailed mechanisms are unknown, sex differences in the gene-related tolerance for diabetes may also explain the stronger association among women found in our study.[36,37]

Although we found a gradient in diabetes by income but not by education or occupation, these results were inconsistent with those among young or middle-aged adults[18] but consistent with results from older populations.[6] Socioeconomic status in older people should be interpreted differently from that at younger ages.[38] In many countries, older people are likely to have lower educational attainment. Among our study participants, the percentage of people with university or higher level educations was small in the age group investigated: 18.3% for men and 10.9% for women (Table 1). However, the university entrance rate in Japan was 56.6% among men and 57.1% among women in 2016.[39] Consequently, the number of older people with high educational attainment is small, resulting in less statistical power to capture the association between education level and diabetes. The null finding between longest occupation and diabetes among men and women may be explained by weak statistical power owing to small sample sizes of each occupational category. For example, among men, the PR of diabetes among unemployed compared with professional/technical workers was large (PR 1.64; 95% CI, 0.68–3.94), which is in line with known occupation-based health disparities around the world (Table 3).[40] Alternatively, the survivor effect could alter the association between education, previous occupation, and diabetes, given that those who are socioeconomically deprived are less likely to survive; this tendency could be stronger in Japan, where many people experienced the life-threatening post-war period.[41]

Apart from those discussed above, four additional limitations in our study should be mentioned. First and foremost, owing to the cross-sectional nature of the study, we cannot exclude the possibility of reverse causation (ie, diabetes causes reduced income). Second, generalizability is limited, as our data were obtained only from regions of central Japan and the study does not include older people with long-term care insurance. Third, selection bias should also be discussed. Our study participants were more health conscious than the general population, as participants were limited to those who underwent health checkups. In Japan, about 38% of the population received health checkups in 2010.[42] Underestimation of the magnitude of SES-related health associations found in this study may be owing to this bias. Nonetheless, our sensitivity analysis using complete cases only showed the same income-based gradient, suggesting the missing did not induce a critical bias to the levels of the income-based gradient in diabetes. Finally, we did not evaluate the health gradient stemming from other SES indicators, including previously suggested indicators associated with health: wealth,[5] relative deprivation,[43] and social exclusion.[35] Specifically, future studies should evaluate the wealth-based gradient given that older adults are more likely to rely on savings or other similar financial resources rather than regular income, which mostly consists of a government pension.

In conclusion, we found a clear income-based gradient in diabetes among Japanese older adults and the gradient was potentially more remarkable among women, but this was not the case for education and longest occupation. This was the first large-scale study clarifying the socioeconomic disparity in diabetes among Japanese older population. Given the findings of this study, monitoring income gradient in diabetes is important in public health actions, even in older populations. Future longitudinal and intervention studies should evaluate the causal link of income to diabetes onset, determine the mechanisms of the potential sex differences in the income/diabetes association, and identify ways to mitigate the income-based inequality.

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APPENDIX A. SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://doi.org/10.2188/jea.JE20170206.

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