Effect of a community intervention programme promoting social interactions on functional disability prevention for older adults: propensity score matching and instrumental variable analyses, JAGES Taketoyo study

Hiroyuki Hikichi,[1,6] Naoki Kondo,[2] Katsunori Kondo,[1,3] Jun Aida,[4] Tokunori Takeda,[5] Ichiro Kawachi[6]

▶ Additional material is published online only. To view please visit the journal online (http://dx.doi.org/10.1136/jech-2014-205345).

[1]Center for Preventive Medical Science, Chiba University, Chiba, Japan
[2]School of Public Health, The University of Tokyo, Tokyo, Japan
[3]Centor for Well-being and Society, Nihon Fukushi University, Nagoya, Japan
[4]Department of International and Community Oral Health, Tohoku University Graduate School of Density, Sendai, Japan
[5]Faculty of Rehabilitation and Care, Seijoh University, Tokai, Japan
[6]Department of Social and Behavioral Sciences, Harvard T. H. Chan School of Public Health, Boston, Massachusetts, USA

Correspondence to
Dr Hiroyuki Hikichi, Department of Social and Behavioral Sciences, Harvard T. H. Chan School of Public Health,401 Park Drive, Landmark Center Room 403-T, Boston, MA 02215, USA; hikichi@hsph.harvard.edu

Received 5 December 2014
Revised 5 March 2015
Accepted 26 March 2015
Published Online First 17 April 2015

To cite: Hikichi H, Kondo N, Kondo K, *et al*. *J Epidemiol Community Health* 2015;**69**:905–910.

ABSTRACT

Background The efficacy of promoting social interactions to improve the health of older adults is not fully established due to residual confounding and selection bias.

Methods The government of Taketoyo town, Aichi Prefecture, Japan, developed a resident-centred community intervention programme called 'community salons', providing opportunities for social interactions among local older residents. To evaluate the impact of the programme, we conducted questionnaire surveys for all older residents of Taketoyo. We carried out a baseline survey in July 2006 (prior to the introduction of the programme) and assessed the onset of functional disability during March 2012. We analysed the data of 2421 older people. In addition to the standard Cox proportional hazard regression, we conducted Cox regression with propensity score matching (PSM) and an instrumental variable (IV) analysis, using the number of community salons within a radius of 350 m from the participant's home as an instrument.

Results In the 5 years after the first salon was launched, the salon participants showed a 6.3% lower incidence of functional disability compared with non-participants. Even adjusting for sex, age, equivalent income, educational attainment, higher level activities of daily living and depression, the Cox adjusted HR for becoming disabled was 0.49 (95% CI 0.33 to 0.72). Similar results were observed using PSM (HR 0.52, 95% CI 0.33 to 0.83) and IV-Cox analysis (HR 0.50, 95% CI 0.34 to 0.74).

Conclusions A community health promotion programme focused on increasing social interactions among older adults may be effective in preventing the onset of disability.

INTRODUCTION

In almost every country, the proportion of older people is growing faster than any other age group. The population of people 60 years or older in the world has doubled since 1980 and is forecast to reach two billion by 2050.[1] Japan, in particular is confronted with population ageing at the fastest pace. The proportion of the Japanese population over the age of 60 years was 32% in 2012 and is projected to rise to 42% by 2050.[2]

To minimise the impact of population ageing on healthcare costs, the Japanese government has prioritised measures that focus on long-term care prevention.[3] One such approach attempts to boost the rates of social participation among older adults.[4] Observational studies suggest that social participation is associated with lower risks of physical and mental problems resulting in functional disability, as well as cardiovascular disease,[5] a decline in motor ability[6] and cognitive function,[7] falls and fractures[8] and frailty.[9] By promoting enjoyable interactions with others and providing individuals with a sense of meaning in life, social participation has been linked to the lowering of psychological distress.[10] Social participation also facilitates access to social support,[11] as well as increased neuronal plasticity for the maintenance of cognitive function.[12 13] However, these studies are prone to confounding biases due to their observational nature, more specifically, selection bias, that is, people who participate in social activities tend to be healthier than those who do not participate.

Evidence is scarce on the effectiveness of community intervention programmes aimed at facilitating social participation and preventing functional disability among older adults. We previously reported observational evidence of an association between participation in a community intervention programme developed in Taketoyo town and improved self-rated health among older adults.[14] In the intervention, community-dwelling seniors were provided opportunities to promote social interactions with other community members in so-called 'community salons' (explained in detail later). However, we do not know whether the community salon intervention is effective for preventing incident functional disability, or the onset of long-term care needs.

In this study, therefore, we evaluated the impact of community salon interventions on the onset of functional disability or long-term care needs. To address the issue of selection bias, we used two identification strategies, namely propensity score matching (PSM) analysis and instrumental variable (IV) analysis.[15] Both techniques attempt to balance treatment and non-treatment groups in terms of the background characteristics that may affect the chance of selecting into treatment.[16]

METHODS

Study population

As a part of the Japan Gerontological Evaluation Study (JAGES), in July 2006 we conducted a mail-in questionnaire survey of all 5759 older

residents of Taketoyo who were physically and cognitively independent and aged 65 years or older. In the Japanese national long-term care insurance system, a municipality certification committee determines the eligibility for receiving services based on an evaluation of each applicant's degree of physical and mental disability, as determined by physical examination.[17] We defined 'Independence' as those who were deemed not to require the use of services covered by the insurance system.[18 19]

In total, 2667 people responded to our invitation, and 2421 were eligible for analysis after excluding volunteers (ie, people who self-selected to assist in organising the salon activities) from the baseline survey. The research team began collaborating with the Taketoyo local government to organise the community salon programme starting in May 2007. We followed the respondents of the baseline survey until 31 March 2012 and collected information on their frequency of participating in salons as well as onset of functional disability. The observation period was 1796 days from 1 May 2007 to 31 March 2012. Our study protocol and informed consent procedure were approved by the Ethics Committee at Seijoh University (No. 2007C0001).

The intervention

Taketoyo is a town with a population of approximately 48 000 residents, located in Aichi prefecture, Japan. The community salon project started in May 2007 when the municipal authorities decided to open a series of community-based centres where the town's senior residents could congregate and participate in social activities, ranging from arts and crafts, games (bingo) and interactive activities with preschool children. The local government recruited volunteers to staff the salons. Initially, three such salons were established, and by 2011 a total of eight salons were in operation. Any resident aged 65 years or older was eligible to participate for a nominal fee of 100 yen (about US$1) per visit.

Outcome variable

Our primary outcome was the onset of functional disability, that is, physical and/or cognitive disability identified from the town's public long-term care insurance database. Since 2001, the Japanese government has operated a national insurance scheme in which eligibility for long-term care (eg, home helpers) is based on a standardised multistep assessment of functional and cognitive impairments based on a physician examination. Individuals are classified into one of six care levels according to the severity of their physical and mental disability, such as functional decline or dementia. The care levels are mainly based on the estimated hours of home care required each week in order to meet their instrumental and basic activities of daily living (eg, bathing, dressing, cleaning the house, preparing meals).[17]

These criteria for determining the onset of disability have been used in previous epidemiological studies and also form the basis of health need assessment by Japanese local governments.[18 19]

Explanatory variable

Our primary treatment variable was whether or not the person participated in a community salon. In total, 437 people visited the salon at least once. Their frequency of participation varied from 1 to 235, with a median of 3 (IQR was 18–1). Among 437 participants, 29.7% (130 people) participated in the salon only once, while 14.0% (61 people) participated twice and 56.3% (246 people) participated three times or more. We defined more than three-time visitors (246 people) as 'participants' because we hypothesised that participation on fewer occasions could not be plausibly expected to prevent functional disability. We also created a continuous variable for the frequency of participation. Since the distribution was right-skewed, we log-transformed the values.

Table 1 Characteristics of subjects at baseline and incidence of functional disability after 5 years

		Non-participants (0–2 times) (n=2175)		Participants (3 times and more) (n=246)		
		N	Per cent	N	Per cent	p Value
Sex	Male	1199	55.1	47	19.1	<0.001
	Female	976	44.9	199	80.9	
	Total	2175	100	246	100	
Age	65–74 years	1502	69.1	155	63.0	0.060
	75 years and over	673	30.9	91	37.0	
	Total	2175	100	246	100	
Educational attainment	10 years and over	987	45.9	95	39.3	0.056
	9 years and under	1165	54.1	147	60.7	
	Total	2152	100	242	100	
Equivalent income	2 million yen (about US$20 000) and more	892	53.4	72	40.9	0.002
	1.99 million yen (about US$19 900) and less	778	46.6	104	59.1	
	Total	1670	100	176	100	
Higher level of ADL	13 points (full marks)	711	36.1	120	53.1	<0.001
	12 points and under	1261	63.9	106	46.9	
	Total	1972	100	226	100	
Depression (GDS-15)	None (0–4 points)	1367	72.7	158	72.5	0.069
	Mild (5–9 points)	387	20.6	37	17.0	
	Severe (10–15 points)	126	6.7	23	10.6	
	Total	1880	100	218	100	
Incidence of functional disability	Non-certification	1870	86.0	227	92.3	0.005
	Certification	305	14.0	19	7.7	
	Total	2175	100	246	100	

GDS-15, Geriatric Depression Scale-15.

Covariates

We selected as potential confounding variables sex, age, educational attainment and equivalent income, higher level activities of daily living (ie, instrumental activities of daily living (ADL), intellectual activities and social roles measured by the Tokyo Metropolitan Institute of Gerontology Index of Competence; TMIG-IC)[20] and depressive symptoms (Geriatric Depression Scale-15; GDS-15)[21] at the baseline survey.[14 22] Age was grouped into: 65–74 years and 75 years or over. Educational attainment was categorised as under 9 vs over 10 years. Household income was equalised by the square root of the number of household members and grouped as over 2 million yen versus under 1.99 million yen. Higher level ADL (instrumental activities of daily living (IADL), intellectual activities, social roles) was split at the median value (12 points). Depressive symptoms were categorised into no risk (under 4 points), mild risk (5–9 points) or high risk (over 10 points).[21]

Statistical analysis

Analyses were performed using STATA V.13.0 (STATA Corp LP., College Station, Texas, USA) and SAS statistical package V.9.4 (SAS Institute Inc., Cary, North Carolina, USA).

After calculating descriptive statistics, we conducted three regression analyses. First, we employed a standard Cox proportional hazard model to estimate the HR and 95% CIs for disability onset according to the number of times the respondent participated in the salons (log-transformed). Multivariate models were adjusted for potential confounders. Next, we conducted Cox regression with a PSM technique which matched individuals on the basis of their probability (ie, propensity) of receiving the treatment (ie, community salon participation) conditional on all the observed covariates.[15]

To calculate the propensity scores, we selected 26 potential variables including the six confounders in a standard Cox proportional hazard model that could theoretically predict the probability of participating in the salons on the basis of previous findings (see online supplementary table S1),[22–29] and predicted participation in community salons three times or more by logistic regression (C-statistic=0.82).

We used one-to-one caliper (0.2) matching with no replacement, to match the treatment and control groups (ie, participants vs non-participants) using Stata command 'psmatch2'.

Lastly, we performed IV analysis.[15] IV analysis can provide unbiased estimates of the effects of treatments in the presence of unobserved confounding. A valid IV needs to be associated with treatment; it must not directly affect the outcome except through its effect on the treatment, and cannot be associated with confounding factors.[30] We used the number of community salons within a radius of 350 m from each respondent's home as the instrument. We created this variable using geographic information systems with geocoded data of each participant's residential addresses and the places where community salons were opened. The conversion from residential addresses to longitude and latitude data was accomplished using a geocoding programme provided by the Center for Spatial Information Science of the University of Tokyo.[31] To test the strength of our instrument, we checked the correlation between the local density of salons and the probability of participation (see online supplementary table S2). We confirmed that the number of community salons within 350 m from a resident's home was related to their frequency of participation (see online supplementary table S3). We performed IV-Cox regression and confirmed that the IV was not weak (F (8, 2412)=20.07). In a two-step

Table 2 Result of the standard and after PSM Cox proportional hazard model

		Categorised model		Log-transformed model		PSM
		Crude model	Multivariate model	Crude model	Multivariate model	
Participation	0–2 times (reference) (n=2175)			–	–	–
	3 times and more (n=246)	0.50 (0.32 to 0.80)***	0.41 (0.26 to 0.66)***			
	Log-transformed (log (X+1))	–	–	0.57 (0.39 to 0.84)**	0.49 (0.33 to 0.72)***	0.52 (0.33 to 0.83)**
Sex	Female (reference: male)	–	1.05 (0.84 to 1.32)	–	1.05 (0.84 to 1.32)	–
Age	75 years and over (reference: 65–74 years)	–	4.87 (3.86 to 6.14)***	–	4.85 (3.85 to 6.12)***	–
Educational attainment	9 years and under (reference: 10 years and over)	–	0.95 (0.76 to 1.19)	–	0.95 (0.76 to 1.19)	–
Equivalent income	¥1.99 million and less (reference: ¥2 million and more)	–	1.14 (0.91 to 1.43)	–	1.14 (0.91 to 1.43)	–
Higher level of ADL	12 points and under (reference: 13 points)	–	1.32 (1.02 to 1.73)*	–	1.32 (1.01 to 1.72)*	–
Depression	None (reference)	–				
	Mild		1.35 (1.04 to 1.75)*	–	1.35 (1.04 to 1.74)*	–
	Severe		2.09 (1.48 to 2.95)***		2.09 (1.48 to 2.95)***	

*p<0.05, **p<0.01, ***p<0.001.
PSM, propensity score matching.

regression procedure, we then regressed the HR of disability onset on the instrumented probability of salon participation. To address potential bias due to missing data, we used multiple imputation assuming MCAR (ie, Missing Completely At Random).

RESULTS

Compared with non-participants, salon participants were more likely to be female (male 19.1% vs female 80.9%, p<0.001), have lower household income (p=0.002) and to be healthier with regard to baseline higher level activities of daily living (p<0.001; table 1). The cumulative incidence of functional disability during the follow-up was lower among participants than non-participants: 7.7% among participants versus 14.0% among non-participants (p=0.005).

Standard Cox regression using categorised participation or not showed a significant result: compared with those participating 2 times and less (non-participants), HR of disability onset among those who participated 3 times and more was 0.50 (95% CI 0.32 to 0.80; table 2). The Cox regression using log-transformed the frequency of participation was significantly associated with lower incidence of functional disability (HR=0.57, 95% CI 0.39 to 0.84).

The multivariate model also indicated the same associations between the incidence of functional disability and participation (HR=0.50, 95% CI 0.32 to 0.80) and the log-transformed variable (HR=0.49, 95% CI 0.33 to 0.72). The sensitivity analysis using categorised participants into two groups based on median (3–13 times 122 people, over 14 times 124 people) also showed similar results (3–13 times, HR=0.43, 95% CI 0.23 to 0.81; 14 times and more, HR=0.39, 95% CI 0.20 to 0.77; see online supplementary table S4).

The application of PSM also showed a significant result. The HR of continuous log-transformed participation frequency was 0.52 (95% CI 0.33 to 0.83; table 2).

When employing IV-Cox, the number of times of participating in the salon was strongly predicted by our instrument, that is, the number of community salons within a radius of 350 m from each participant's address: coefficient 0.04, 95% CI 0.01 to 0.06. The IV estimates on the incidence of functional disability (HR=0.50, 95% CI 0.34 to 0.74) were similar to those of the standard Cox proportional hazard model (table 3).

DISCUSSION

Our study found that participation in the community salon contributed to the prevention of incident functional disability, even after the application of PSM and IV analysis. Previous observational studies showed that participation is effective for prevention of functional disability.[22] Our finding is consistent with these findings.

There are several plausible pathways linking participation in the community salon and prevention of incident functional disability. First, exercise in the salon may contribute to the maintenance of physical and cognitive function. Some salon activities involved light physical activity such as callisthenics,[32] handicraft,[33] chess[34] and calligraphy,[35] which may have contributed to the maintenance of physical and cognitive functions. Second, it is possible that the activities of the community salon helped to establish new social connections, thereby increasing the chances of obtaining more social support, which is a predictor of health for older people.[36]

The strength of this study is the use of multiple identification strategies for reducing selection bias under a quasi-experimental study design. The instrument used, that is, the density of community salons within a radius of 350 m from residential addresses, was significant (F (8, 2412)=20.07). The results were highly consistent across models employed, supporting their robustness. The use of objective measures is another strength: the frequency of salon participation and the names of the salons were officially recorded by community salon organisers. The outcome variable was acquired from the public insurance database, based on the physician's examination.[18 19]

Previous observational studies suggested that social participation is associated with the prevention of functional disability.[5–7] However, there are few intervention studies. Ichida *et al*[14] previously assessed the Taketoyo intervention study 1 year into the programme, and reported showed that salon participation improved self-rated health using IV analysis, but they did not examine whether participation contributed to the prevention of functional disability. On the other hand, 'Experience Corps' and

Table 3 Result of IV-Cox analysis

		IV-Cox	
		Second stage **Dependent variable: incidence of functional disability** **HR**	**First stage** **Dependent variable: number of participations** **Coefficient**
Endogenous variable	Participation (log-transformation)	0.50 (0.34 to 0.74)**	–
Exogenous variable	Number of community salons within a radius of 350 m from the subject's home	–	0.04 (0.01 to 0.06)**
Sex	Female (reference: male)	9.00 (3.62 to 22.41)***	0.15 (0.12 to 0.18)***
Age	75 years and over (reference: 65–74 years)	7.29 (5.48 to 9.70)***	0.03 (−0.01 to 0.06)
Educational attainment	9 years and under (reference: 10 years and over)	1.18 (0.93 to 1.51)	0.02 (−0.01 to 0.05)
Equivalent income	¥1.99 million and less (reference: ¥2 million and more)	2.21 (1.55 to 3.16)***	0.05 (0.02 to 0.08)**
Higher level of ADL	12 points and under (reference: 13 points)	0.50 (0.31 to 0.81)**	−0.07 (−0.10 to −0.03)***
Depression	None (reference)		
	Mild	0.92 (0.68 to 1.24)	−0.03 (−0.06 to 0.01)
	Severe	4.63 (2.87 to 7.48)***	0.04 (0.01 to 0.06)**
Constant	Constant	–	−0.11 (−0.17 to −0.06)*

In the first-stage regression of 2SLS, F-statistics was 20.07 (p<0.001), and partial R^2 was 0.06.
*p<0.05, **p<0.01, ***p<0.001.
IV, instrumental variable.

'REPRINTS' are two community-based intervention studies in which participants were assigned to social programmes. Experience Corps recruited retired seniors in Baltimore, USA, to serve as a volunteer teacher's aides in local schools. The programme was designed to support the academic success of children and to promote the health of older volunteers by enhancing their physical, social and cognitive functioning.[37] The intervention was reported to improve the physical mobility of the participants.[38] REPRINTS is a programme modelled on Experience Corps, which was launched in Japan, which recruited senior volunteers to read to school-aged children in educational settings.[39] According to Murayama *et al*,[40] the programme was associated with decreased depressive mood. These programmes did not report on whether participation resulted in a significant impact on the prevention of functional disability.

Our study has several limitations. First, our study participants may not be generalisable to the older residents of Taketoyo due to the <50% response to the baseline survey. Generalisability is further limited by the fact that our study was conducted in a single town in Japan.

Nevertheless, our findings suggest that the opening of community-based centres (salons) is a viable intervention for encouraging social participation among Japanese seniors, and that they may be effective for the prevention of disability onset. Future studies should evaluate the cost-effectiveness of this approach as part of determining whether the intervention can be rolled out to communities in the rest of the country.

What is already known on this subject

- Observation studies have shown that participating in community activities by the elderly is effective to prevent the onset of functional disability.
- There is limited evidence that the intervention programme to promote interaction among older residents is effective for the prevention of functional disability.

What this study adds

- Promoting social participation in the elderly is an effective means of preventing the onset of functional disability.
- Community salons promote the opportunity for older residents to interact socially and thereby avoid functional disability.

Acknowledgements The authors thank other JAGES group members. Members of the JAGES group are as follows: KK (the lead investigator), Hanazato M, HH, Miyaguni Y, Sasaki Y, Nagamine Y, Chiba University, Chiba; Ashida T, NK, Takagi D, Tani Y, The University of Tokyo, Tokyo; JA, Osaka K, Tsuboya T, Tohoku University, Miyagi; Jeong S, Murata C, Saito T, National Center for Geriatrics and Gerontology, Aichi; Ojima T, Okada E, Hamamatsu University School of Medicine, Shizuoka; Shirai K, Todoriki H, University of the Ryukyus, Okinawa; Saito M, Nihon Fukushi University, Aichi; Hirai H, Iwate University, Iwate; Misawa J, Rikkyo University, Tokyo; Suzuki K, Aichi Gakuin University, Aichi; Ichida Y, Doctoral Institute for Evidence Based Policy, Tokyo; Takeda T, Seijoh University, Aichi; Yamamoto T, Kanagawa Dental University, Kanagawa; Nakade M, Tokaigakuen University, Aichi; Cable N, University College London, London; Tamakoshi A, Hokkaido University Graduate School of Medicine, Hokkaido; Fujino Y, University of Occupational and Environmental Health, Fukuoka; Shobugawa Y, Niigata University, Niigata; Hayashi T, Tokai College of Medical Science, Aichi.

Correction notice This article has been corrected since it published Online First. The article now has the Open Access license.

Contributors HH was responsible for the study conception, design, analysis and interpretation of the data, as well as the drafting of the article. NK and JA intensively revised the manuscript. IK lent support on the conception and intensively revised the manuscript. KK and TT acquired the data and intensively revised the manuscript.

Funding This work was supported by the MEXT-Supported Program for the Strategic Research Foundation at Private University, 2009-2013; Grant-in-Aid for Scientific Research (23243070); Grant-in-Aid for Scientific Challenging Exploratory Research (24653150); and Health Labour Sciences Research Grant, Comprehensive Research on Aging and Health (H25-Choju-Ippan-003).

Competing interests None declared.

Ethics approval Our study protocol and informed consent procedure were approved by the Ethics Committee at Seijoh University (No. 2007C0001).

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1 WHO. 10 fact on ageing and the life course. Secondary 10 fact on ageing and the life course 2012. http://www.who.int/features/factfiles/ageing/en/
2 International UaH. *Aging in the twenty-first century: a celebration and a challenge*. UNFPA and HelpAge International, 2012.
3 Ministry-of-Health-Labour-and-Welfare. Syakai Hosyou Seido Kaikaku No Zentai Zou. in Japanese ed, 2013. [in Japanese].
4 Ministry-of-Health-Labour-and-Welfare. Kaigo Yobou Manual Kaiteiban: Health-Labor-and-Welfare-Ministry, 2012. [in Japanese].
5 Kamiya Y, Whelan B, Timonen V, *et al*. The differential impact of subjective and objective aspects of social engagement on cardiovascular risk factors. *BMC Geriatr* 2010;10:81.
6 Buchman AS, Boyle PA, Wilson RS, *et al*. Association between late-life social activity and motor decline in older adults. *Arch Intern Med* 2009;169:1139–46.
7 Glei DA, Landau DA, Goldman N, *et al*. Participating in social activities helps preserve cognitive function: an analysis of a longitudinal, population-based study of the elderly. *Int J Epidemiol* 2005;34:864–71.
8 Luukinen H, Koski K, Laippala P, *et al*. Factors predicting fractures during falling impacts among home-dwelling older adults. *J Am Geriatr Soc* 1997;45:1302–9.
9 Welmer AK, Morck A, Dahlin-Ivanoff S. Physical activity in people age 80 years and older as a means of counteracting disability, balanced in relation to frailty. *J Aging Phys Act* 2012;20:317–31.
10 Takagi D, Kondo K, Kawachi I. Social participation and mental health: moderating effects of gender, social role and rurality. *BMC Public Health* 2013;13:701.
11 Tobin MC, Drager KDR, Richardson LF. A systematic review of social participation for adults with autism spectrum disorders: support, social functioning, and quality of life. *Res Autism Spectr Disord* 2014;8:214–29.
12 Dishman RK, Berthoud HR, Booth FW, *et al*. Neurobiology of exercise. *Obesity (Silver Spring)* 2006;14:345–56.
13 Kramer AF, Erickson KI, Colcombe SJ. Exercise, cognition, and the aging brain. *J Appl Physiol* 2006;101:1237–42.
14 Ichida Y, Hirai H, Kondo K, *et al*. Does social participation improve self-rated health in the older population? A quasi-experimental intervention study. *Soc Sci Med* 2013;94:83–90.
15 Khandker SR, Koolwal GB, Samad H. *Handbook on impact evaluation: quantitative methods and practices*. Washington DC: World Bank, 2010.
16 De Ridder A, De Graeve D. Can we account for selection bias? A comparison between bare metal and drug-eluting stents. *Value Health* 2011;14:3–14.
17 Kurimori S, Fukuda Y, Nakamura K, *et al*. Calculation of prefectural disability-adjusted life expectancy (DALE) using long-term care prevalence and its socioeconomic correlates in Japan. *Health Policy* 2006;76:346–58.
18 Aida J, Kondo K, Kawachi I, *et al*. Does social capital affect the incidence of functional disability in older Japanese? A prospective population-based cohort study. *J Epidemiol Community Health* 2013;67:42–7.
19 Kondo N, Kawachi I, Hirai H, *et al*. Relative deprivation and incident functional disability among older Japanese women and men: prospective cohort study. *J Epidemiol Community Health* 2009;63:461–7.
20 Koyano W, Shibata H, Nakazato K, *et al*. Measurement of competence: reliability and validity of the TMIG Index of Competence. *Arch Gerontol Geriatr* 1991;13:103–16.

21 Almeida OP, Almeida SA. Short versions of the geriatric depression scale: a study of their validity for the diagnosis of a major depressive episode according to ICD-10 and DSM-IV. *Int J Geriatr Psychiatry* 1999;14:858–65.
22 Kanamori S, Kai Y, Aida J, *et al*. Social participation and the prevention of functional disability in older Japanese: the JAGES cohort study. *PLoS ONE* 2014;9:e99638.
23 Bygren LO, Konlaan BB, Johansson SE. Attendance at cultural events, reading books or periodicals, and making music or singing in a choir as determinants for survival: Swedish interview survey of living conditions. *BMJ* 1996;313:1577–80.
24 Glass TA, de Leon CM, Marottoli RA, *et al*. Population based study of social and productive activities as predictors of survival among elderly Americans. *BMJ* 1999;319:478–83.
25 Iwasaki M, Otani T, Sunaga R, *et al*. Social networks and mortality based on the Komo-Ise cohort study in Japan. *Int J Epidemiol* 2002;31:1208–18.
26 Chiao C, Weng LJ, Botticello AL. Social participation reduces depressive symptoms among older adults: an 18-year longitudinal analysis in Taiwan. *BMC Public Health* 2011;11:292.
27 James BD, Boyle PA, Buchman AS, *et al*. Relation of late-life social activity with incident disability among community-dwelling older adults. *J Gerontol A Biol Sci Med Sci* 2011;66:467–73.
28 Rosso AL, Taylor JA, Tabb LP, *et al*. Mobility, disability, and social engagement in older adults. *J Aging Health* 2013;25:617–37.
29 Takeuchi K, Aida J, Kondo K, *et al*. Social participation and dental health status among older Japanese adults: a population-based cross-sectional study. *PLoS ONE* 2013;8:e61741.
30 Thomas KH, Martin RM, Davies NM, *et al*. Smoking cessation treatment and risk of depression, suicide, and self harm in the Clinical Practice Research Datalink: prospective cohort study. *BMJ* 2013;347:f5704.
31 Center for Spatial Information Science TUoT. *Geocoding tools & utilities*. Secondary Geocoding Tools & Utilities, 2014. http://newspat.csis.u-tokyo.ac.jp/geocode/
32 Turner LW, Bass MA, Ting L, *et al*. Influence of yard work and weight training on bone mineral density among older U.S. women. *J Women Aging* 2002;14:139–48.
33 Sugano K, Yokogawa M, Yuki S, *et al*. Effect of cognitive and aerobic training intervention on older adults with mild or no cognitive impairment: a derivative study of the nakajima project. *Dement Geriatr Cogn Disord Extra* 2012;2:69–80.
34 Chiu YC, Huang CY, Kolanowski AM, *et al*. The effects of participation in leisure activities on neuropsychiatric symptoms of persons with cognitive impairment: a cross-sectional study. *Int J Nurs Stud* 2013;50:1314–25.
35 Kwok TC, Bai X, Kao HS, *et al*. Cognitive effects of calligraphy therapy for older people: a randomized controlled trial in Hong Kong. *Clin Interv Aging* 2011;6:269–73.
36 Sato T, Kishi R, Suzukawa A, *et al*. Effects of social relationships on mortality of the elderly: how do the influences change with the passage of time? *Arch Gerontol Geriatr* 2008;47:327–39.
37 Martinez IL, Frick K, Glass TA, *et al*. Engaging older adults in high impact volunteering that enhances health: recruitment and retention in The Experience Corps Baltimore. *J Urban Health* 2006;83:941–53.
38 Parisi JM, Rebok GW, Seeman TE, *et al*. Lifestyle activities in sociodemographically at-risk urban, older adults prior to participation in the Baltimore Experience Corps ((R)) Trial. *Activities Adapt Aging* 2012;36:242–60.
39 Fujiwara Y, Sakuma N, Ohba H, *et al*. REPRINTS: effects of an Intergenerational Health Promotion Program for older adults in Japan. *J Intergenerational Relationships* 2009;7:17–39.
40 Murayama Y, Ohba H, Yasunaga M, *et al*. The effect of intergenerational programs on the mental health of elderly adults. *Aging Ment Health* 2014:1–9.