Title: The association between social participation and cognitive function in community-dwelling elderly populations: Japan Gerontological Evaluation Study at Taisetsu Community Hokkaido

Running head: social participation and cognitive function

Key words: aged, cognition disorders, multilevel analysis, Japan, social capital, social participation

Key points:

- This cross-sectional study examined the association between the number of area- and individual-level social participation items and cognitive function in the community-dwelling elderly population of three towns in Japan.
- Participating in many kinds of social activities preserved cognitive function in the elderly population even after adjusting for area-level social participation variables.

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Abstract

Objective: To study the association between the number of area- and individual-level social participation items and cognitive function in the community-dwelling elderly populations of three towns in Hokkaido, Japan.

Methods: A survey on the frequency of social participation was mailed to those in the Japan Gerontological Evaluation Study 2013 who were aged ≥65 years, were not certified as needing long-term care, and lived in Higashikawa, Higashikagura, or Biei. A subset of participants aged 70-74 years completed the Japanese version of the Montreal Cognitive Assessment in a home visit survey. Both the area- and individual-level social participation and demographic information were obtained on the self-administered questionnaire. A multilevel analysis using a generalized linear mixed-effects model was used to examine the association between variables in the area- and individual-level social participation items and cognitive function.

Results: Out of 4,042 respondents, data from 2,576 were used in the area-level analysis. Of those, 180 were aged 70-74 years and completed the home visit survey for the individual-level analysis. A greater number of higher social participation items at the individual level was associated with higher cognitive function scores after adjusting for area-level social participation variables and confounders (regression coefficient: 0.19; 95% confidence interval: 0.03, 0.35). There were no significant associations between area-level social participation item averages and individual-level cognitive function scores.

Conclusions: Elderly populations participating in many kinds of social activities exhibited preserved cognitive function even after adjusting for area-level social participation variables.

Introduction

Dementia is a syndrome in which there is deterioration in memory, thinking, orientation, comprehension, calculation, learning capacity, language, and judgment (World Health Organization, 2015). It is one of the leading causes of disability and dependency among older people worldwide (World Health Organization, 2015). Diabetes, midlife hypertension, midlife obesity, smoking, and physical inactivity are known to be risk factors for dementia (World Health Organization, 2015). In Japan, the number of patients with dementia is increasing, and the prevalence is estimated at 16.4% (Wada-Isoe et al., 2012). Dementia is the second most common cause of long-term care in Japan according to the Japan social long-term care insurance system (Ministry of Health, Labour and Welfare, 2013a). However, there is no treatment available to cure dementia or to alter its progressive course (World Health Organization, 2015); therefore, prevention of cognitive decline is necessary.

There has been an increasing application of the concept of social capital (SC) in public health (Rouxel et al., 2015; De Silva et al., 2005; Murayama et al., 2012; Islam et al., 2006). Putnam defines SC as “features of social organization such as trust, norms and networks that can improve the efficacy of society by facilitating coordinated actions” (Putnam, 1993) and as a key characteristic of communities (Putnam, 2000). SC is also described as resources that are accessed by a person as a result of membership of a network or a group (eds Berkman, Kawachi, and Glymour, 2014). There are two levels of SC: individual- and group-level (eds Berkman, Kawachi, and Glymour, 2014). Individual-level SC refers to resources accessed by the individual through their ego-centered networks, whereas group-level SC is regarded as a property of the whole social network (eds Berkman, Kawachi, and Glymour, 2014). Social participation, an indicator of social cohesion, is an index of SC, although there is no agreement on a common definition (Levasseur et al., 2010). However, one definition of social participation mostly focuses on a “person’s involvement in activities

that provide interaction with others in society or the community" through content analysis (Levasseur et al., 2010).

Focusing on social participation and cognitive function, some cross-sectional studies reported that participation in some social activity items were associated with higher levels of cognitive function (Maselko et al., 2014; Lee, 2015). Also, several longitudinal studies reported that participation in some, a few, or many types of social activities was associated with a reduced risk of cognitive decline (Niti et al., 2008; Iwasa et al., 2012; Leung et al., 2011; Hsu, 2007; Glei et al., 2005) and dementia (Akbaraly et al., 2009; Scarmeas et al., 2001). In particular, an association between engaging and stimulating leisure activities occurred not only with general dementia (composed of Alzheimer's disease, mixed and vascular dementia, and other dementias; American Psychiatric Association, 1994), but also with Alzheimer's disease independently (Akbaraly et al., 2009). Furthermore, participation in cognitive activities was associated with reduced deposition of β-amyloid, a major constituent in Alzheimer's disease (Landau et al., 2012). Thus, participation in social activities could possibly prevent the progression of dementia.

If living in areas with high levels of area-level social participation preserves cognitive function for elderly people, public administration sources such as municipal governments can provide measures of dementia by area units, and it may be efficient and effective in public health service. However, to the best of our knowledge, there is no study investigating the association between individual- and area-level social participation and cognitive function. This study aimed to study the association between both the number of area- and individual-level social participation items and cognitive function in the community-dwelling elderly population of three towns in Hokkaido, Japan.

Methods

Study participants

This cross-sectional study is a part of the Japan Gerontological Evaluation Study 2013 (JAGES2013). JAGES2013 was conducted from October to December 2013 and has been described elsewhere (Tani et al., 2015). In short, it is an ongoing cohort study that enrolled 195,290 community-dwelling individuals from 30 municipalities in 14 prefectures throughout Japan who were aged 65 years or older and were not eligible for long-term care (Ministry of Health, Labour and Welfare, 2013b). Of those, we further restricted the survey to participants living in the three towns of Higashikawa, Higashikagura, and Biei in Hokkaido, northern Japan. The population of each town in 2010 was 7,859, 9,292, and 10,956, respectively, and the percentage of people aged 65 years or older was 28.0%, 22.5%, and 33.5%, respectively. The major industry of each town is farming. Participants were further narrowed to those aged 70-74 years due to financial restrictions of the study, and because the number of people needing long-term care drastically increases at age 75 or older (Cabinet Office, 2014). In 2013, self-administered questionnaires were directly mailed. For those respondents who agreed to participate in an additional survey, we conducted a home visit survey in 2014 to assess their cognitive function.

This study was approved by the Ethics Review Committee of the Hokkaido University Graduate School of Medicine and Nihon Hukushi University. Written informed consent was assumed with voluntary return of the mailed questionnaire and by a signed consent form after explanation of the study by investigators for the home visit.

Measurements

Social activities involved 14 items, including volunteer groups, sports groups or clubs, hobby groups, senior citizen clubs, neighborhood or residents' associations, learning and culture clubs, long-term care prevention and health promotion activities, teaching activities for skills and experience, community events, supporting activities for elderly needing care, supporting

activities for elderly needing long-term care, supporting activities for parents raising a child, improving community environment, and other groups or organizations. Participants were queried on the frequency of each social activity: “How often do you participate in the following groups?” Possible answers were 4 or more times per week, 2-3 times per week, 1 time per week, several times per year, or never. For each question, participants were further combined into two groups (presence or absence) after calculating the cumulative proportion for each response in all participants. Here, a cumulative proportion reaching 50% was considered the cut-off point for attendance. Demographic factors such as age and sex were obtained from the municipal government.

Outcome measurement

Cognitive function was assessed using the Japanese version of the Montreal Cognitive Assessment (MoCA-J) (Fujiwara et al., 2010, Nasreddine et al., 2005) during a home visit. The MoCA-J assesses six domains of cognition: memory; visuospatial abilities; executive functions; attention, concentration, and working memory; language; and time and place orientations (Fujiwara et al., 2013). The total MoCA-J score ranges from 0 to 30; a higher score indicates higher cognitive function. To correct for an education effect, 1 point was added for participants with a total MoCA-J score of fewer than 30 points and an educational attainment of 12 years or less. MoCA-J subscores were also calculated in each domain of cognition. The home visit was conducted by 5 qualified medical care personnel such as a nurse, social worker, clinical psychologist, and nursing care manager. To prevent measurement bias, they were trained in the appropriate assessment of the MoCA-J by lectures and role playing before home visits.

Statistical analyses

Continuous variables are presented as means ± standard deviation (SD); categorical variables are presented as numbers (percentages). Individual-level social participation was defined as

the number of social activities participants had attended. If the participants did not positively respond to any of the 14 social activities items, then they were excluded from the analysis. Area-level social participation was calculated as the average number of individual total social participation items using data from all JAGES2013 participants in the 14 public elementary school areas in Higashikawa, Higashikagura, and Biei. Public elementary school areas are defined as the primary residential spatial unit of people in Japan and generally represent a geographical scale in which the elderly can travel easily by foot or bicycle (Takagi et al., 2013).

A multilevel analysis using a generalized linear mixed-effects model was used to examine the association among variables for individual- and area-level social participation items and cognitive function. Demographic information such as sex, age (as a continuous variable), living alone (yes, no, unknown), equalized annual income (≤2, >2 million yen, unknown), education (≤9, >9 years, unknown), smoking status (current/former, never smokers, unknown), drinking status (current/former, never drinkers, unknown), physical performance (deteriorated, not deteriorated, unknown), and depression (presence, absence, unknown) were introduced into the model as confounders.

Equalized annual income was calculated by the square root of household size (Organization for Economic Co-operation and Development, 2014). Physical performance was measured using items relevant to motor organs from a basic checklist from the Ministry of Health, Labor and Welfare (Fukutomi et al., 2015). A deterioration in physical performance was defined as a score of less than 3 points (out of a total of 5 points). Depression was evaluated using the Geriatric Depression Scale Short Form (Yeasavage, 1986), in which scores range from 0-15. The presence of depression was defined as a score of more than 5 points. An alpha level of 0.05 was considered statistically significant. All statistical analyses were performed using JMP 11.0 software (SAS Institute Inc.).

Results

Of the 6,239 people who met the criteria (aged at least 65 years; lived in Higashikawa, Higashikagura, or Biei; and did not need long-term care before April 2013) and received the questionnaire, 4,042 returned it (Figure 1). After excluding those participants aged <70 or ≥75 years (n = 2,948), who obtained certification of long-term care need (n = 6), who moved out (n = 2), who refused to participate in further mail surveys (n=287), and who refused to participate in the home visit survey (n=538), 261 participants agreed to participate in the home visit survey. Of those, 81 were excluded due to a history of stroke (n = 11) or for missing data for MoCA-J (n = 2) and/or social participation (n = 72). This left 180 participants who were included in the final individual-level analysis. The average number of area-level social participation items was calculated from the 2,576 (out of 4,042) participants who were not missing data for public elementary school area (n = 59) and/or social participation (n = 1,426).

The number of mean social participation items was similar among the 14 districts in the three towns studied (Table 1).

Table 2 shows the mean proportion of social participation items in the area-level analysis (n = 2,576). The mean number of social participation items was 2.7. About 40% of participants participated in community events and/or activities improving the community environment. In contrast, the percentages of social participation in neighborhood or residents' associations, supporting activities for elderly needing care/long-term care, and parents raising a child were each less than 10%.

Characteristics of the study participants at the individual level (n=180) are shown in Table 3. The mean age of participants was 71.6 years, 64% of the participants were male, 83% of participants lived with others, more than half had an equalized annual income less than 200

million yen, 66% were educated ≥9 years, 31% were current/ever smokers, 49% were current/ever drinkers, 86% had preserved physical performance, and 14% had depression symptoms. The mean number of social participation items was 4.0.

Table 4 provides the association between the number of social participation items and several individual-level variables, as well as cognitive function scores. Intra-class correlation among public elementary school areas was 0.06 (null model), meaning that the data have a hierarchical structure. Greater numbers of social participation items at the individual level were associated with higher cognitive function scores after adjusting for confounding factors (model 2). This association remained even after adjustment for area-level social participation variables and confounders (model 4: regression coefficient, 0.19; 95% confidence interval: 0.03, 0.35). There were no significant associations between the mean number of social participation items in the area-level and individual-level cognitive function scores (models 3 and 4).

Table 5 provides the association between the number of social participation items and cognitive function subscores. A higher number of social participation items at the individual-level was associated with a higher visuospatial abilities score (regression coefficient: 0.05; 95% confidence interval: 0.02, 0.09) and executive-function score (regression coefficient: 0.06; 95% confidence interval: 0.003, 0.11) after adjusting for area-level social participation variables and confounders. There were no significant associations between the mean number of area-level social participation items and any cognitive function subscores.

Discussion

The results from our study indicate that a greater number of social participation items at the individual level was significantly associated with higher cognitive function scores, although

there was no significant association between the number of social participation items at the public elementary school area-level and individual-level cognitive function scores. A population-based cohort study in community-dwelling older Japanese adults indicated that only 40% of participants had stable MoCA-J performance over a 1-year period, which is operationally defined as no change or a change of no more than 1 point (Suzuki et al., 2015). Therefore, our results appear relevant to the preservation of cognitive function. Furthermore, to our knowledge, this is the first study investigating the association between the numbers of social participation items both at individual- and area-levels and cognitive function.

Prior work has shown that people who participated in one or more social activities such as playing a game, socializing with friends/neighbors/relatives, joining organized group activities, doing volunteer work, or participating in religious groups, business associations, political groups, clan associations, or elderly organizations were at a reduced risk of cognitive impairment compared to those involved in no social activities (Glei et al., 2005). Also, a higher level of participation in intellectual activities such as reading books, investing in or following the stock market, participating in forums or discussions, making handicrafts, or playing a musical instrument in late life was significantly associated with less cognitive decline (Leung et al., 2011). People with a high leisure score (an aggregation of the number of social participation items calculated from 13 leisure activities such as having a hobby; going on walks or excursions; visiting friends or relatives; physical conditioning; going to movies, restaurants, or sporting events; reading; watching television; doing community volunteer work; playing cards; and attending a club or center, classes, or church/ synagogue/temple) had a decreased risk of incident dementia compared to those with low scores (Scarmeas et al., 2001). Our results were consistent with these previous studies (Leung et al., 2011; Scarmeas et al., 2001; Glei et al., 2005).

The possible mechanisms involved in our findings are unclear. However, we infer that three pathways, stress reduction, a wider social network, and varied cognitive stimulation, should explain the effect of a higher number of social participation items on preserving cognitive function at the individual level. First, active people who have many opportunities to interact with others have higher positive emotional states, which leads to stress reduction (Fratiglioni et al., 2004), than those who do not. On a physiological level, chronic stress is negatively associated with cognitive dimensions in the hypothalamic-pituitary-adrenal (HPA) axis (Wilson et al., 2009; Kremen et al., 2012). Parts of the human brain, such as the hippocampus, including the dentate gyrus (Eriksson et al., 1998; Benarroch, 2013), retain their ability to generate neurons throughout life (Steindler and Pincus, 2002). However, glucocorticoids such as cortisol are an end-product of the HPA axis (Levine et al., 2007) and inhibit neurogenesis (Reagan and McEwen, 1997; Gould et al., 1999). Higher salivary cortisol levels, known to reflect blood cortisol (Kirschbaum and Hellhammer, 1994), were significantly associated with poorer performance in the cognitive domains of executive measures, processing speed, and visual-spatial memory (Franz et al., 2011). Thus, social participation may lead to retention of neurons and brain structure due to decreased chronic cortisol exposure. Second, high levels of social participation and healthy behaviors such as not smoking, leisure-time physical activity, daily consumption of vegetables, and adequate duration of sleep were beneficial in preserving cognitive abilities (Lee et al., 2010; Nieminen et al., 2013). In another study, smoking cessation by a person such as a friend decreased one's chances of smoking; that is, smoking behavior spreads through social ties (Christakis and Fowler, 2008). Varied social participation and health-associated behavior may contribute to preserving cognitive function through self-health management. In addition, some kinds of social participation such as hobbies (Iwasa et al., 2012), productive leisure activities (Niti et al., 2008), and intellectual activities (Leung et al., 2011) were reported to prevent declining

cognitive function. Stimulating leisure activities such as attending organization meetings, doing crosswords, or practicing an artistic activity were also associated with a reduced risk of dementia (Akbaraly et al., 2009). The concept of cognitive reserve, which was proposed by Stern, is “based on more efficient utilization of brain networks or of enhanced ability to recruit alternate brain networks as needed” (Stern, 2002). This idea was developed from the concept of brain reserve, which includes brain size or synapse count (Stern, 2002). Cognitive reserve parallels the brain reserve in coping with brain damage, and it consists of the ability to use alternate paradigms to approach a problem when the standard approach is no longer operational (Stern, 2002). Therefore, varied cognitive stimulation caused by large amounts of social participation may preserve cognitive function and thus enhance cognitive reserves.

Although no significant association with cognitive function scores was observed, there are three proposed explanations relating to contextual/group-level mechanisms: social contagion, informal social control, and collective efficacy (Berkman, Kawachi, and Glymour, 2014). We predict that individuals possessing a high proportion of social participation items at the area-level 1) are encouraged to participate socially, 2) have opportunities to communicate with people on a daily basis, permitting early intervention, and 3) receive beneficial results from active social participation.

Our study has several limitations. First, reverse causality could occur due to the nature of the cross-sectional design. Individuals with high cognitive function may participate in many kinds of social activities, although we excluded participants who had a history of stroke and dementia, and we adjusted for possible confounders as much as possible. Further longitudinal studies are needed to resolve this limitation. Second, this study was conducted in three adjacent towns in Hokkaido, a northern island of Japan. There was little difference in the area-level social participation among their public school areas. Results from a previous study in the JAGES 2010 wave indicate that the percentage of social participation differed among

school districts (n=141) (Kondo, 2016). Although we evaluated cognitive function among only people living in one area with 14 school districts, there was a dose-response association between individual-level social participation and cognitive function. Also we observed a positive but not statistically significant relationship between the number of social participation items at the public elementary school area-level and cognitive function scores. Comparing areas with different features will clarify the effect of area-level social participation on cognitive function. Third, a selection bias of participants with high health consciousness might be included in this study. Although we adjusted cognition-related variables such as smoking status, alcohol drinking habit, educational attainment, depressive status, and physical function, the amount of social participation in 180 study participants was higher than that in area-level participants. Thus, it is difficult to generalize the results. Forth, the 2,576 participants comprised 41.3% of the eligible elderly populations, so selection bias may be a factor in the average number of area-level social participation items. To assess this bias, we conducted a sensitivity analysis using the data on participants who answered at least one question of social participation (n = 3,649; 58.5% of eligible elderly populations), and our results were not essentially changed.

Conclusion

In conclusion, the present study indicated that elderly populations participating in many social activities, compared with those involved in few items of social activity, preserved their cognitive function even after adjustment for area-level social participation variables. Future national and multiple-area longitudinal studies are needed to examine this causality and further investigate the preventive effects of social participation on cognitive decline.

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Conflict of interest

None to disclose.

Appendix1.

Members of the JAGES group are as follows: Kondo K. (the lead investigator), Hanazato M., Hikichi H., Miyaguni Y., Sasaki Y., Nagamine Y., Chiba University, Chiba; Ashida T., Kondo N., Takagi D., Tani Y., The University of Tokyo, Tokyo; Aida J., 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.

References

Akbaraly, T. N., Portet, F., Fustinoni, S., Dartigues, J. F., Artero, S., Rouaud, O., Touchon, J., Ritchie, K. & Berr, C. 2009. Leisure activities and the risk of dementia in the elderly: results from the Three-City Study. *Neurology,* **73** : 854-61.

American Psychiatric Association. 1994. *Diagnostic and Statistical Manual of Mental Disorders: DSM-IV*. Washington, DC: American Psychiatric Association.

Benarroch, E. E. 2013. Adult neurogenesis in the dentate gyrus: general concepts and potential implications. *Neurology,* **81** : 1443-52.

Berkman, L.F., Kawachi, I. & Glymour, M. M(eds). 2014. *Social Epidemiology*. Oxford University Press: United States of America.

Cabinet Office. 2014. *Annual Report on the Aging Society: 2014 (Summary) Chapter 1 Situation on Aging Section 2 Current State and Trends on the Elderly and their Environment* [Online]. Available: http://www8.cao.go.jp/kourei/english/annualreport/2014/pdf/c1-2-2.pdf [Accessed February 12 2016].

Christakis, N. A. & Fowler, J. H. 2008. The collective dynamics of smoking in a large social network. *N Engl J Med,* **358** : 2249-58.

De Silva, M. J., Mckenzie, K., Harpham, T. & Huttly, S. R. 2005. Social capital and mental illness: a systematic review. *J Epidemiol Community Health,* **59** : 619-27.

Eriksson, P. S., Perfilieva, E., Bjork-Eriksson, T., Alborn, A. M., Nordborg, C., Peterson, D. A. & Gage, F. H. 1998. Neurogenesis in the adult human hippocampus. *Nat Med,* **4** : 1313-7.

Franz, C. E., O'brien, R. C., Hauger, R. L., Mendoza, S. P., Panizzon, M. S., Prom-Wormley, E., Eaves, L. J., Jacobson, K., Lyons, M. J., Lupien, S., Hellhammer, D., Xian, H. & Kremen, W. S. 2011. Cross-sectional and 35-year longitudinal assessment of salivary

cortisol and cognitive functioning: the Vietnam Era twin study of aging. *Psychoneuroendocrinology,* **36** : 1040-52.

Fratiglioni, L., Paillard-Borg, S. & Winblad, B. 2004. An active and socially integrated lifestyle in late life might protect against dementia. *Lancet Neurol,* **3** : 343-53.

Fujiwara, Y., Suzuki, H., Yasunaga, M., Sugiyama, M., Ijuin, M., Sakuma, N., Inagaki, H., Iwasa, H., Ura, C., Yatomi, N., Ishii, K., Tokumaru, A. M., Homma, A., Nasreddine, Z. & Shinkai, S. 2010. Brief screening tool for mild cognitive impairment in older Japanese: validation of the Japanese version of the Montreal Cognitive Assessment. *Geriatr Gerontol Int,* **10** : 225-32.

Fujiwara, Y., Suzuki, H., Kawai, H., Hirano, H., Yoshida, H., Kojima, M., Ihara, K. & Obuchi, S. 2013. Physical and sociopsychological characteristics of older community residents with mild cognitive impairment as assessed by the Japanese version of the Montreal Cognitive Assessment. *J Geriatr Psychiatry Neurol,* **26** : 209-20.

Fukutomi, E., Okumiya, K., Wada, T., Sakamoto, R., Ishimoto, Y., Kimura, Y., Chen, W. L., Imai, H., Kasahara, Y., Fujiwara, M., Otsuka, K. & Matsubayashi, K. 2015. Relationships between each category of 25-item frailty risk assessment (Kihon Checklist) and newly certified older adults under Long-Term Care Insurance: A 24-month follow-up study in a rural community in Japan. *Geriatr Gerontol Int,* **15** : 864-71.

Glei, D. A., Landau, D. A., Goldman, N., Chuang, Y. L., Rodriguez, G. & Weinstein, M. 2005. Participating in social activities helps preserve cognitive function: an analysis of a longitudinal, population-based study of the elderly. *Int J Epidemiol,* **34** : 864-71.

Gould, E., Beylin, A., Tanapat, P., Reeves, A. & Shors, T. J. 1999. Learning enhances adult neurogenesis in the hippocampal formation. *Nat Neurosci,* **2** : 260-5.

Hsu, H. C. 2007. Does social participation by the elderly reduce mortality and cognitive impairment? *Aging Ment Health,* **11** : 699-707.

Islam, M. K., Merlo, J., Kawachi, I., Lindstrom, M. & Gerdtham, U. G. 2006. Social capital and health: does egalitarianism matter? A literature review. *Int J Equity Health,* **5** : 3.

Iwasa, H., Yoshida, Y., Kai, I., Suzuki, T., Kim, H. & Yoshida, H. 2012. Leisure activities and cognitive function in elderly community-dwelling individuals in Japan: a 5-year prospective cohort study. *J Psychosom Res,* **72** : 159-64.

Kirschbaum, C. & Hellhammer, D. H. 1994. Salivary cortisol in psychoneuroendocrine research: recent developments and applications. *Psychoneuroendocrinology,* **19** : 313-33.

Kondo, K. 2016. Progress in aging epidemiology in Japan: The JAGES Project. *J epidemiol,* 26: 331-6.

Kremen, W. S., Lachman, M. E., Pruessner, J. C., Sliwinski, M. & Wilson, R. S. 2012. Mechanisms of age-related cognitive change and targets for intervention: social interactions and stress. *J Gerontol A Biol Sci Med Sci,* **67** : 760-5.

Landau, S. M ., Marks, S. M., Mormino, E. C., Rabinovici, G. D., Oh, H.,O'Neil, J. P., Wilson, R. S. & Jagust, W. T. 2012. Association of lifetime cognitive engagement and low β -amyloid deposition. *Arch Neurol.*, 69 : 623-29.

Lee, P. L. 2015. Cognitive function in midlife and beyond: physical and cognitive activity related to episodic memory and executive functions. *Int J Aging Hum Dev,* **79** : 263-78.

Lee, Y., Back, J. H., Kim, J., Kim, S. H., NA, D. L., Cheong, H. K., Hong, C. H. & Kim, Y. G. 2010. Systematic review of health behavioral risks and cognitive health in older adults. *Int Psychogeriatr,* **22** : 174-87.

Leung, G. T., Fung, A. W., Tam, C. W., Lui, V. W., Chiu, H. F., Chan, W. M. & Lam, L. C. 2011. Examining the association between late-life leisure activity participation and global cognitive decline in community-dwelling elderly Chinese in Hong Kong. *Int J Geriatr Psychiatry,* **26** : 39-47.

Levasseur, M., Richard, L., Gauvin, L. & Raymond, E. 2010. Inventory and analysis of definitions of social participation found in the aging literature: proposed taxonomy of social activities. *Soc Sci Med,* **71** : 2141-9.

Levine, A., Zagoory-Sharon, O., Feldman, R., Lewis, J. G. & Weller, A. 2007. Measuring cortisol in human psychobiological studies. *Physiol Behav,* **90** : 43-53.

Maselko, J., Sebranek, M., Mun, M. H., Perera, B., Ahs, J. & Ostbye, T. 2014. Contribution of generative leisure activities to cognitive function in elderly Sri Lankan adults. *J Am Geriatr Soc,* **62** : 1707-13.

Ministry of Health, Labour and Welfare. 2013a. *Annual Health, Labour, and Welfare Report 2011-2012 [10]Health and Welfare Services for for the Elderly* [Online]. Available: http://www.mhlw.go.jp/english/wp/wp-hw6/dl/10e.pdf [Accessed February 12 2016].

Ministry of Health, Labour and Welfare. 2013b. *The current situation and the future direction of the Long-term Care Insurance System in Japan* [Online]. Available: http://www.mhlw.go.jp/english/policy/care-welfare/care-welfare-elderly/dl/ri_130311-01.pdf [Accessed February 12 2016].

Murayama, H., Fujiwara, Y. & Kawachi, I. 2012. Social capital and health: a review of prospective multilevel studies. *J Epidemiol,* **22** : 179-87.

Nasreddine, Z. S., Phillips, N. A., Bedirian, V., Charbonneau, S., Whitehead, V., Collin, I., Cummings, J. L. & Chertkow, H. 2005. The Montreal Cognitive Assessment, MoCA: a brief screening tool for mild cognitive impairment. *J Am Geriatr Soc,* **53** : 695-9.

Nieminen, T., Prattala, R., Martelin, T., Harkanen, T., Hyyppa, M. T., Alanen, E. & Koskinen, S. 2013. Social capital, health behaviours and health: a population-based associational study. *BMC Public Health,* **13** : 613.

Niti, M., Yap, K. B., Kua, E. H., Tan, C. H. & Ng, T. P. 2008. Physical, social and productive leisure activities, cognitive decline and interaction with APOE-epsilon 4 genotype in Chinese older adults. *Int Psychogeriatr,* **20** : 237-51.

Organization for Economic Co-operation and Development. 2014. *OECD Project on Income Distribution and Poverty WHAT ARE EQUIVALENCE SCALES?* [Online]. Available: http://www.oecd.org/eco/growth/OECD-Note-EquivalenceScales.pdf [Accessed February 12 2016].

Putnam, R. D. 1993. *Making Democracy Work: Civic Traditions in Modern Italy,* Princeton University Press: United States of America.

Putnam, R. D. 2000. *Bowling alone: the collapse and revival of American community.,* Simon and Schuster: New York.

Reagan, L. P. & McEwen, B. S. 1997. Controversies surrounding glucocorticoid-mediated cell death in the hippocampus. *J Chem Neuroanat,* **13** : 149-67.

Rouxel, P. L., Heilmann, A., Aida, J., Tsakos, G. & Watt, R. G. 2015. Social capital: theory, evidence, and implications for oral health. *Community Dent Oral Epidemiol,* **43** : 97-105.

Steindler, D. A. & Pincus, D. W. 2002. Stem cells and neuropoiesis in the adult human brain. *Lancet,* **359** : 1047-54.

Stern, Y. 2002. What is cognitive reserve? Theory and research application of the reserve concept. *J Int Neuropsychol Soc,* **8** : 448-60.

Suzuki, H., Kawai, H., Hirano, H., Yoshida, H., Ihara, K., Kim, H., Chaves, P.H., Minami, U., Yasunaga, M., Obuchi, S. & Fujiwara, Y. 2015. One-year change in the Japanese

version of the Montreal Cognitive Assessment performance and related predictors in community-dwelling older adults. *J Am Geriatr Soc,* **63** : 1874-9.

Takagi, D., Kondo, K. & Kawachi, I. 2013. Social participation and mental health: moderating effects of gender, social role and rurality. *BMC Public Health,* **13** : 701.

Tani, Y., Sasaki, Y., Haseda, M., Kondo, K. & Kondo, N. 2015. Eating alone and depression in older men and women by cohabitation status: The JAGES longitudinal survey. *Age Ageing,* **44** : 1019-26.

Wada-Isoe K, Uemura Y, Nakashita S, Yamawaki M, Tanaka K, Yamamoto M, Shimokata H, Nakashima K. 2012. Prevalence of dementia and mild cognitive impairment in the rural island town of Ama-cho, Japan. *Dement Geriatr Cogn Dis Extra* **2** : 190-9.

World Health Organization. 2015. *Dementia* [Online]. Available: http://www.who.int/mediacentre/factsheets/fs362/en/ [Accessed February 12 2016].

Wilson, R. S., Hebert, L. E., Scherr, P. A., Barnes, L. L., Mendes De Leon, C. F. & Evans, D. A. 2009. Educational attainment and cognitive decline in old age. *Neurology,* **72** : 460-5.

Yeasavage, J. A. 1986. Geriatric Depression Scale(GDS): Recent Evidence and Development of a Shorter version. *Clinical gerontologist,* **5** : 165-173.

Table 1. The number of social participation items at the area level (n = 2,576)

		Number of social participation items
Public elementary school area	n	Mean ± SD
Higashikawa town	710	
Higashikawa-Daiichi	69	2.5 ± 2.7
Higashikawa-Daini	66	2.9 ± 3.2
Higashikawa-Daisan	73	2.9 ± 3.4
Higashikawa	502	2.3 ± 2.7
Higashikagura town	760	
Tosei	326	2.6 ± 2.7
Higashikagura	384	3.0 ± 3.2
Tyuei	42	3.3±3.2
Shibinai	8	2.0 ± 1.2
Biei town	1,106	
Biei	602	2.6 ± 2.8
Bibaushi	74	2.5 ± 2.7
Bisawa	30	2.8 ± 2.5
Meitoku	18	2.2 ± 2.3
Bishin	38	2.9 ± 2.1
Bieihigashi	344	2.8 ± 2.9

SD, standard deviation

Table 2. Social participation for the area-level analysis (n = 2,576)

Social participation items, n (%)	
Volunteer groups	470 (18.2)
Sports groups or clubs	694 (26.9)
Hobby groups	848 (32.9)
Senior citizen clubs	517 (20.1)
Neighborhood or residents' associations	215 (8.3)
Learning and culture clubs	357 (13.9)
Long-term care prevention and health promotion activities	378 (14.7)
Teaching activities for skills and experience	289 (11.2)
Community events	961 (37.3)
Supporting activities for elderly needing care	228 (8.9)
Supporting activities for elderly needing long-term care	179 (7.0)
Supporting activities for parents raising a child	167 (6.5)
Activities improving community environment	1033 (40.1)
Other groups or organizations	502 (19.5)
Number of social participation items, mean ± SD	2.7 ± 2.9

SD, standard deviation

Table 3. Characteristics of participants in the individual-level analysis (n=180)

Variables, n (%)		
Sex	Male	116 (64.4)
Age (years)		71.6±1.3
Resident status	Non-solitary	150 (83.3)
	Solitary	17 (9.4)
	Unknown	13 (7.2)
Equalized annual income (million yen)	≥200	61 (33.9)
	<200	95 (52.8)
	Unknown	24 (13.3)
Education (years)	≥9	119 (66.1)
	<9	61 (33.9)
Smoking status	Current/Ever	56 (31.1)
	Never	121 (67.2)
	Unknown	3 (1.7)
Drinking status	Current/Ever	88 (48.9)
	Never	90 (50.0)
	Unknown	2 (1.1)
Physical performance	Deteriorated	20 (11.1)
	Not Deteriorated	155 (86.1)
	Unknown	5 (2.8)
Depression	Presence	26 (14.4)
	Absence	135 (75.0)
	Unknown	19 (10.6)
Number of social participation items, mean ± SD		4.0 ± 3.3

SD, standard deviation

Table 4. Association between the number of social participation items and cognitive function scores

	Variables	n	Model 1	Model 2	Model 3	Model 4
Constant			23.30	30.50	24.53	27.45
Individual-level variable*						
Education (years)	≥9	180		2.48 (1.37, 3.59)	2.77 (1.67, 3.87)	2.48 (1.37, 3.60)
Depression	Presence	180		0.79 (-0.66, 2.24)	0.54 (-0.92, 2.0)	-0.05 (-1.07, 0.97)
Social participation	The number of social participation items	180		0.19 (0.03, 0.35)		0.19 (0.03, 0.35)
Area-level variable*						
Social participation	The mean number of social participation items	11			1.14 (-2.96, 5.25)	1.03 (-2.96, 5.03)
Random parameters						
Area-level variance (standard error)			0.72 (0.66)	0.78 (0.65)	1.13 (0.89)	1.02 (0.83)
Intra-class correlation			0.06	0.07	0.10	0.09

*Regression coefficient and 95% confidence interval.

Model 1 was the null model; Model 2 included social participation at the individual level and it was adjusted for social participation at the individual level and confounding factors (sex, age, living alone, equalized annual income, education, smoking status, drinking status, physical performance, and depression); Model 3 included social participation at the area level and it was adjusted for confounding factors; Model 4 included social participation at the individual- and area-level and was adjusted for confounding factors.

Table 5. Association between the number of social participation items and cognitive function subscores

	Variables	n	Memory	Visuospatial abilities	Executive functions	Attention, concentration, and working memory	Language	Time and place orientation
Constant			19.19	7.63	-8.68	-4.54	3.53	6.71
Individual-level variable[*]								
Social participation	The number of social participation items	180	0.07 (-0.01, 0.15)	0.05 (0.02, 0.09)	0.06 (0.003, 0.11)	0.02 (-0.03, 0.08)	-0.02 (-0.07, 0.03)	0.02 (-0.01, 0.05)
Area-level variable[*]								
Social participation	The mean number of social participation items	11	-0.14 (-2.20, 1.92)	-0.13 (-0.89, 0.63)	0.72 (-0.81, 2.25)	-0.07 (-1.00, 0.86)	0.32 (-0.40, 1.03)	-0.02 (-0.73, 0.70)
Random parameters								
Area-level variance (standard error)[‡]			0.15 (0.19)	0.01 (0.02)	0.18 (0.14)	0.02 (0.03)	-0.01 (0.01)	0.01 (0.01)
Intra-class correlation			0.06	0.01	0.14	0.01	-0.01	0.04

[*]Regression coefficient and 95% confidence interval.

Adjusted for sex, age, living alone, equalized annual income, education, smoking status, drinking status, physical performance and depression; possible ranges were 0-5 for memory score; 0-4 for visuospatial abilities and executive functions scores; and 0-6 for attention, concentration, and working memory as well as for language and time and place orientation scores.

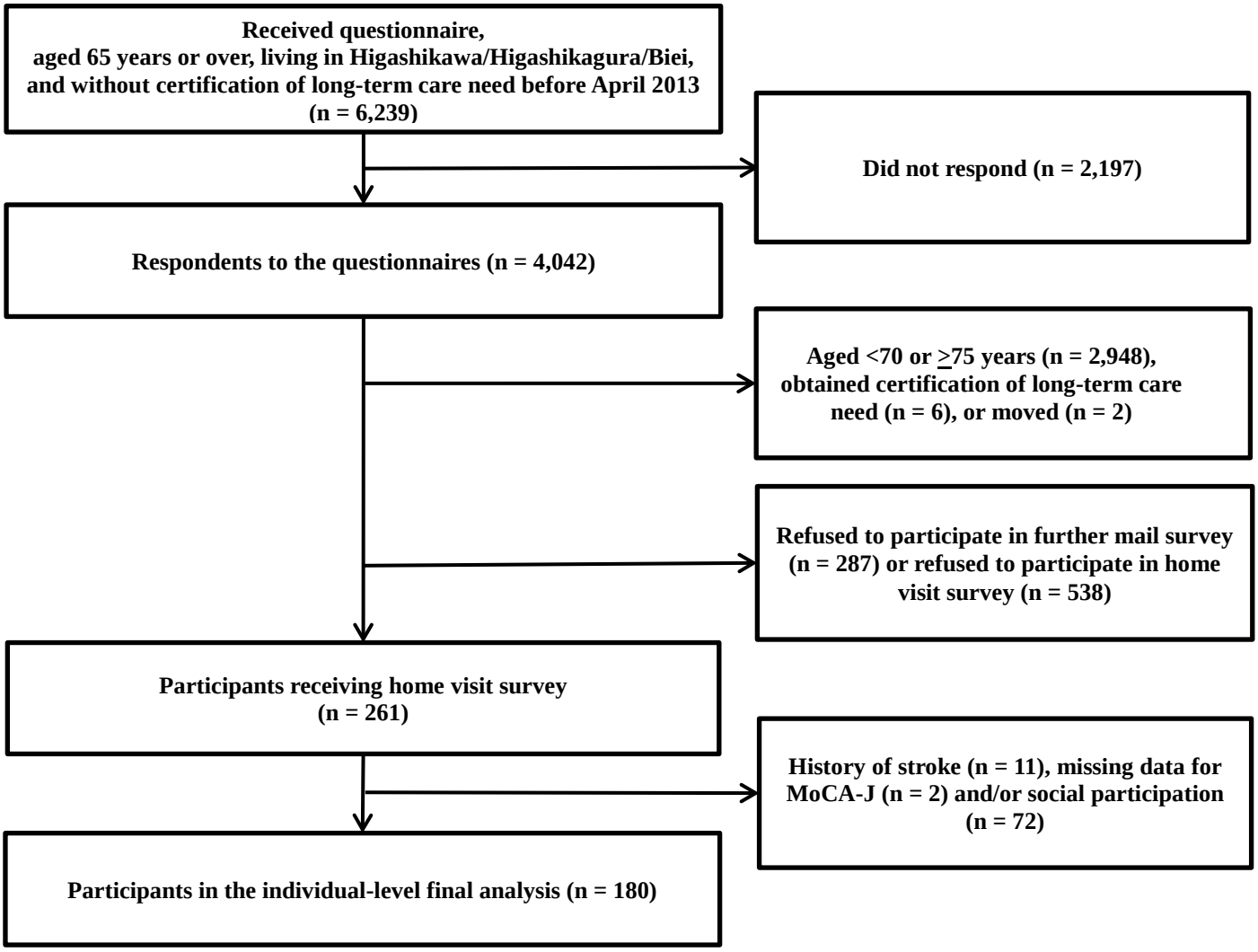

Figure 1. Flow chart of the enrollment of study participants
MoCA-J, Japanese version of the Montreal Cognitive Assessment