Post-disaster Changes in Social Capital and Mental Health: A Natural Experiment from the 2016 Kumamoto Earthquake

Koryu Sato, Airi Amemiya, Maho Haseda, Daisuke Takagi, Mariko Kanamori, Katsunori Kondo, Naoki Kondo

Correspondence to Mr. Koryu Sato, Department of Health Education and Health Sociology, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8654, Japan (email: kos639@mail.harvard.edu; Phone: +81-3-5841-3513, FAX: +81-3-5684-6083)

Author Affiliations: Department of Health Education and Health Sociology, The University of Tokyo, Bunkyo-ku, Tokyo, Japan (Koryu Sato, Airi Amemiya, Maho Haseda, Mariko Kanamori, and Naoki Kondo); Department of Health and Social Behavior, The University of Tokyo, Bunkyo-ku, Tokyo, Japan (Daisuke Takagi and Naoki Kondo); Department of Social Preventive Medical Sciences, Center for Preventive Medical Sciences, Chiba University, Chiba City, Chiba, Japan (Katsunori Kondo); and Department of Gerontological Evaluation, Center for Gerontology and Social Science, National Center for Geriatrics and Gerontology, Obu City, Aichi, Japan (Katsunori Kondo).

Funding: This study used data from JAGES (the Japan Gerontological Evaluation Study), which was supported by JSPS (Japan Society for the Promotion of Science), KAKENHI Grant Number (JP15H01972), Health Labour Sciences Research Grant (H28-Choju-Ippan-002, H29-Chikyuukibo-Ippan-001, H30-Junkankitou-Ippan-004, 19FA1012, 19FA2001), Japan Agency for Medical Research and Development (AMED) (JP17dk0110017, JP18dk0110027, JP18ls0110002, JP18le0110009, JP19dk0110034, JP19dk0110037), and the Research Funding for Longevity Sciences from National Center for Geriatrics and Gerontology (29-42).

Conflict of interest: none declared.

Running head: Social Capital and Mental Health After a Disaster

Abstract

Levels of social capital can change after a natural disaster; thus far, no study has examined how changes in social capital affect the mental health of disaster victims. This study examined how pre-disaster social capital and its changes after a disaster were associated with the onset of mental disorders. In October 2013, we mailed a questionnaire to participants of the Japan Gerontological Evaluation Study living in Mifune town (Kumamoto, Japan) and measured pre-disaster social capital. In April 2016, the Kumamoto earthquake struck the region. Three years after the baseline survey, post-disaster social capital and symptoms of mental disorders were measured using the Screening Questionnaire for Disaster Mental Health (SQD) (n = 828). A multiple Poisson regression indicated that a standard deviation of 1 in pre-disaster social cohesion at community-level reduced the risk of depression (relative risk [RR] = 0.44); a decline in social

capital after the disaster elevated the risk among women (RR = 2.44). In contrast to social cohesion, high levels of social participation at community-level were positively associated with the risk of depression among women. Policymakers should pay attention to gender differences and the types of social capital when leveraging social capital for recovery from disasters.

Key words: depression, natural disaster, natural experiment, social capital, social cohesion, the 2016 Kumamoto earthquake

Abbreviations: CI, confidence interval; JAGES, the Japan Gerontological Evaluation Study; MDE, major depressive episode; PTSD, posttraumatic stress disorder; RR, relative risk; SQD, Screening Questionnaire for Disaster Mental Health.

The mental health of older people in the aftermath of natural disasters is a crucial public health issue. A meta-analysis of research in this regard showed that older adults face 2.11 and 1.73 times higher risks of post-traumatic stress disorder (PTSD) and adjustment disorder than young adults after natural disasters, respectively (1).

High levels of social capital, defined as “resources that are accessed by individuals as a result of their membership of a network or a group” (2), are associated with lower risk of psychological distress after natural disasters (3). It should be noted that levels of social capital can differ before and after natural disasters. Some researchers have pointed out that social capital would be negatively influenced by disasters, and that residents would have more difficulty in maintaining communications and social relations than they did pre-disaster (4,5). In contrast, other scholars have argued that social capital increases in the aftermath of disasters as

communities tend to cooperate when coping with difficult situations (6,7). Despite the ongoing debate, however, no study has examined how changes in social capital affect the mental health of disaster victims, as pre-disaster social capital is hardly ever measured (3).

The present study makes use of a unique dataset comprising community-dwelling older adults of Mifune town in the Kumamoto prefecture of Japan. The town was one of the participants in the Japan Gerontological Evaluation Study (JAGES), and it completed the baseline survey in 2013. In April 2016, three major earthquakes with a moment magnitude (Mw) of at least 6.0 struck Kumamoto in succession. Mifune town is located approximately 10 kilometers southeast of the epicenter of the main shock and was severely affected by the disaster (Figure 1); more than 196 000 people were evacuated, and 272 people lost their lives (8). The Kumamoto earthquake seriously damaged survivors' health. The number of certified disaster-related deaths by indirect causes (e.g., venous thrombosis, PTSD, and stress during evacuation, exacerbation of symptoms among hospitalized patients, and suicide) was four times more than that of deaths caused by the earthquakes directly (8). A follow-up survey was conducted in Mifune seven months after the earthquakes. Thus, we were able to assess both pre- and post-disaster levels of social capital.

We leveraged this "natural experiment" to examine how pre-disaster levels of social capital and their changes after a disaster affect mental outcomes, specifically major depressive episode (MDE) and PTSD.

METHODS

The baseline survey

The present study is a part of the JAGES, an ongoing nationwide cohort study of Japanese people aged 65 or older who are physically and cognitively independent (9). Mifune town is an inland municipality in Kumamoto prefecture and one of the JAGES study sites. In

2013, the town had a total population size of 17 888, with people aged 65 or older comprising 27.7% (4953 people) of the population. A flowchart of the analytic sample is presented in Figure 2. We collaborated with the municipal office of Mifune town, and the town randomly sampled a half of residents aged 65 or older who had not been certified as needing long-term public care or any supports (eligibility for long-term care is determined by a municipality, based on the assessment of a trained municipal employee (10)), from the complete list of insured persons. The baseline survey was mailed to 2000 eligible older individuals in October 2013, and included questions on socioeconomic status, physical and functional status, mental health, and social participation (see (9) for more detail). The response rate was 71.6% (n=1,432), and 125 participants whose gender and age could not be confirmed or were reported in error were excluded.

Follow-up survey

Three years after the baseline survey, the proportion of residents aged 65 or older in Mifune increased to 31.9% (5649 out of 17 705 people). On April 14, 2016, an earthquake of Mw 6.2 struck Kumamoto prefecture, followed by an earthquake of Mw 6.0 on April 15 and the main shock of Mw 7.0 on April 16. There were also three major aftershocks measuring between Mw 5.2 and Mw 5.8 on the same day.

In November 2016, seven months after the earthquakes, a follow-up survey including questions about experiences during the earthquakes was conducted in Mifune town. The town mailed the follow-up questionnaire to all residents aged 65 or older, excluding those who were certified as needing long-term care but including those who needed supports for preventive long-term care. Those who had died, moved to other towns, or became disabled were lost to follow-up, and a total of 831 participants who participated in the baseline survey returned questionnaires, corresponding to a follow-up rate of 63.6%. Three participants who seemed to

report erroneous ages in the follow-up were excluded from analysis. Our study sample ultimately comprised 828 individuals (361 men and 467 women). A comparison of characteristics between the analytic sample and non-respondents at the follow-up is presented in Web Table 1. The study protocol was reviewed and approved by ethics committees at the University of Tokyo, Nihon Fukushi University, National Center for Geriatrics and Gerontology, and Chiba University.

Outcome variable

The symptoms of PTSD and MDE were assessed using the Screening Questionnaire for Disaster Mental Health (SQD) (11), in 2016. The SQD was developed and psychiatrically validated against the Japanese-language version of the Clinician Administered PTSD Scale (12) and the Structured Clinical Interview for DSM-III-R Major Depression Section (13) as gold standards among victims of the Great Hanshin-Awaji earthquake. It was designed in a simple interview format, mindful of use among older populations, and comprises a total of 12 questions (nine items on PTSD and six on MDE, with some overlap). The cut-off points were determined at 5/6 points on probable PTSD and 4/5 points on probable MDE. In the present study, we created binary variables according to the predefined cut-off points. At the baseline, we did not measure the symptoms of PTSD and MDE using SQD. However, we measured the symptoms of depression using the Geriatric Depression Scale in the short form (14), and adjusted for its score.

Explanatory variable

Our primary explanatory variable was social capital measured before and after the earthquakes. Hikichi and colleagues (15–17) developed scales of social capital representing a cognitive dimension (“social cohesion”) and a structural dimension (“informal socializing and social participation”), and we applied the same scales to this study. Social cohesion was measured

by three questions on trust, mutual support, and community attachment, rated on a five-point Likert scale. Informal socializing and social participation were evaluated through four questions on frequency of meeting friends, the number of friends met over the past month, frequency of participation in sports and hobby groups, rated on a five- or six-point Likert scale. We included actual questions in Web Appendix and the results of confirmatory factor analysis for the scales of social capital in Web Figure 1. Individual-level social capital was calculated by summing the score of each item of the subcategories, with higher scores indicating higher levels of social capital. In addition, we added community-level social capital to our regression model because previous studies have found that community-level variations in the prevalence of mental disorders cannot be fully explained by individual-level variations in the availability of social capital in the aftermath of disasters (15,18). Community-level social capital was obtained as the average score of individual responses within a school district, following other literature (19,20). A school district often represents the socio-geographic area of a former village, and community activities such as senior citizens clubs, agricultural cooperatives, and local festivals are organized within each district. Mifune town included 10 school districts in 2013, and the older population size of each district varied from approximately 120 to 1600. The scores of individual- and community-level social capital were standardized to z-scores to avoid multicollinearity and for ease of interpretation. In addition, we used the difference in scores of social capital measured in 2013 and 2016 (subtracting the 2016 score from the 2013 score) as an index of change in social capital.

Covariates

We adjusted for potential confounders measured at the baseline, namely: gender; age (65-69, 70-74, 75-79, 80-84, and ≥85 years); educational attainment (≤9 years, 10-12 years, and

≥13 years); annual equivalized household income (<2.0 and ≥2.0 million Japanese Yen); family composition (living alone or with others); self-reported medical condition (no illness and having illness); the baseline depressive symptoms (not depressed with the Geriatric Depression Scale of 4 points or less; moderately depressed at 5-9 points; and depressed at more than10 points); and population density of each school district. We also controlled for whether the municipality had certified their housing was certified as having sustained minor or worse damage and whether the individual had moved due to the earthquakes; both were measured through the follow-up survey.

Statistical analysis

We used multiple Poisson regression with robust standard errors to examine the association of social capital with mental health outcomes (21). Our model was specified as follows:

$$\ln(\lambda_i) = \beta_0 + \beta_1 indSC_{13i} + \beta_2(indSC_{13i} - indSC_{16i}) + \beta_3 comSC_{13i} + \beta_4(comSC_{13i} - comSC_{16i}) + X_i^{'}\gamma$$

where λ_i is expected cases of MDE and PTSD in 2016; β_0 is a constant term; β_1 is a coefficient for individual-level social capital in 2013; β_2 is a coefficient for changes in individual-level social capital (the score of 2013 minus that of 2016); β_3 is a coefficient for community-level social capital in 2013; β_4 is a coefficient for changes in community-level social capital; and $X_i^{'}\gamma$ is a vector of covariates and their coefficients. We adjusted for the baseline scores of social capital to examine the associations of pre-disaster social capital and to eliminate the possibility of "regression to the mean (22)." We also conducted multilevel analyses in consideration of heterogeneity across school districts. The intraclass correlation coefficient was <0.1%, and the estimated random effects had wide confidence intervals; we therefore reported results from pooled data without a hierarchical structure. We also adopted a multiple membership model to

take into account the duration of time that each resident had spent in different school districts, given that 19% of participants had moved due to the disaster, and obtained similar results to a pooled model (Web Table 2).

To address potential bias caused by missing values, we adopted multiple imputation under the missing at random assumption. Incomplete variables were imputed by multivariate normal model using all the variables as explanatory variables: gender; age; years of education; equivalized household income; family composition; self-reported medical conditions; score on the Geriatric Depression Scale; the seven items of social capital; housing damage; relocation; and the 12 items of the SQD. We created 20 imputed datasets, and the estimates were combined. All analyses were performed using Stata, version 14.2 (Stata Corp, College Station, TX).

RESULTS

Table 1 delineates the characteristics of the participants. After the earthquakes, 44.8% reported their housing was certified to have minor or worse damage, while 18.8% reported that they had moved to other places because of the disaster. The proportion of participants with MDE symptoms was 7.6%, and 16.7% presented with PTSD symptoms.

In Figure 3, Panel A depicts changes in the community-level score of social cohesion, while Panel B depicts that of informal socializing and social participation. In school areas such as C, I, and J, social capital decreased after the disaster. These areas are mountainous and were also damaged from landslides in the rainy season after the earthquakes (23). On the other hand, in school areas such as A, B, and E, social capital increased after the disaster. These areas are flat, with a younger population and higher population density than the mountainous areas (23).

In Model 1 (Table 2), we adjusted for pre-disaster social capital and other covariates and found that the model considering pre-disaster social capital only could not predict the onset of

MDE well. After adjusting for changes in social capital in Model 2, a standard deviation of 1 in pre-disaster social cohesion (a cognitive dimension of social capital) at community level was associated with a 41% reduction in the risk of MDE (relative risk [RR] = 0.59, 95% confidence interval [CI]: 0.37, 0.95), while its change (i.e., decline in a standard deviation of 1 in the score) was associated with an 88% increase (RR = 1.88, 95% CI: 1.17, 3.03). The estimation of the risk of PTSD showed the same directions as MDE, but it had broader CIs in the adjusted model. In contrast to social cohesion, there were no associations between the structural dimension of social capital and MDE and PTSD. For sensitivity analysis, we excluded participants who reported depressive symptoms, with the Geriatric Depression Scale of 10 points or higher at baseline, from the analysis (Web Table 3).

In addition, we separately analyzed the data for men and women, considering a potential gender difference in the relationship between social capital and mental health (24) (Table 3). For men, social cohesion at individual-level was moderately associated with the risk of MDE (for pre-disaster social cohesion at individual-level: RR = 0.65, 95% CI: 0.41, 1.03, P value = 0.07; for its decline: RR = 1.40, 95% CI: 0.98, 1.99, P value = 0.06). On the other hand, for women, social cohesion at community-level was strongly associated with the risk of MDE (for pre-disaster social cohesion at community-level: RR = 0.44, 95% CI: 0.24, 0.78; for its decline: RR = 2.44, 95% CI: 1.33, 4.47). In contrast to social cohesion, pre-disaster informal socializing and social participation at community-level increased the risk of MDE (RR = 2.36, 95% CI: 1.43, 3.91), while its decline reduced the risk (RR = 0.35, 95% CI: 0.16, 0.79) among women.

DISCUSSION

This is the first study to show how pre-disaster levels of social capital and their changes at post-disaster affected the risk of mental disorders among community-dwelling older adults.

Mifune town had made efforts to build community social capital and had the highest rate of participation in social activities among the 38 municipalities participating in JAGES 2016. In the present study, we observed changes in levels of social capital before and after the earthquakes. Some communities in mountainous areas had high levels of social capital, which was damaged by the disaster, possibly due to residents' prolonged refuge caused by subsequent landslides. On the other hand, communities in flat areas showed increased community-level social capital in the aftermath of the earthquakes. An increase in local cooperative actions had been observed in the wake of earthquakes in Japan, where residents drew water from the river and fought fires together during the 1995 Great Hanshin-Awaji earthquake (25). After the Great Kanto earthquake in 1923, neighborhood associations spread and engaged in relief work and patrolling (26).

Social capital is often conceptualized from cognitive aspects (i.e., "social cohesion" including concepts of trust in others, mutual support, and attachment to the community) and structural aspects (i.e., "informal socializing and social participation" referring to extent and intensity of social relations and participation in civic activities) (27). Two systematic reviews showed that cognitive social capital is consistently associated with lower risks of common mental disorders, whereas evidence for structural social capital has been mixed (28,29). Three studies have suggested a positive association of structural social capital with an increased risk of mental health (30–32). In line with these previous studies, we found that cognitive social capital benefits female victims of the disaster, while structural social capital can harm their mental health. In a community with a high level of structural social capital, one may feel pressure to provide support to others, and members of out-groups may feel isolated due to in-group solidarity (33).

Furthermore, social capital is measured as both an individual-level and community-level variable (34). While community-level variations in the prevalence of mental disorders cannot be fully explained by individual-level variations in the availability of social capital in the aftermath

of disasters, community-level social capital does, in fact, influence individual mental health outcomes (15,35,36), through several plausible pathways. For example, communities where neighbors support each other may make residents feel more secure and suppress the occurrence of psychosocial stressors such as looting, dumping of waste, and fights (34). In addition, communities with high levels of social capital (also referred to as "collective efficacy") can transmit health-related information rapidly and organize necessary medical support effectively (2). Community-level social capital can thus benefit even those who have limited access to social capital at the individual level. Our findings suggest that social cohesion at individual level may be important for men to maintain their mental health, while women were more likely to be protectively affected by social cohesion at community-level. Given that women tend to have larger and more diverse networks than men (37), women may be more sensitive to community social capital.

The major strength of this study is its study design, which was a natural experiment. A recent review (3) showed that most previous studies failed to assess pre-disaster levels of social capital and mental health and thus could not infer causality. One exception is the study by Hikichi et al. (15), which used pre- and post-disaster data of the city of Iwanuma (Tohoku region, Japan), which was affected by the 2011 Great East Japan earthquake and tsunami. The authors showed that pre-disaster community social cohesion would contribute to the resilience of communities and that its pre-assessment would provide planners with valuable information about the prediction of mental health needs in the aftermath of a disaster. However, this study did not take into account post-disaster changes in social capital. Natural disasters not only alter physical landscapes but also the shape of communities. For example, the relocation to prefabricated temporary public housing (resembling Federal Emergency Management Agency-style trailer housing in the United States) affects post-disaster social capital. Following the Great East Japan

earthquake, people who had been assigned temporary housing through a random lottery and found themselves surrounded by strangers experienced the loss of social cohesion and opportunities for social participation (16). Such changes in community social capital should therefore be considered to address mental health problems in disaster-affected areas. Furthermore, Hikichi et al. (15) conducted a follow-up survey approximately 2.5 years after the disaster, and may have failed to capture those who had experienced PTSD just after the disaster but recovered before the follow-up study, given that other studies reported that the prevalence of PTSD decreased by approximately half in the first two years after an earthquake (38,39). In contrast, we conducted a follow-up survey seven months after the earthquakes, which enabled us to capture mental disorders occurring immediately after the earthquakes.

Despite these strengths, the present study has several limitations. First, our study showed potential for selection bias because participants were collected through a postal survey. We found that participants were more likely to be young, married, and living with someone, compared to the whole older population captured by the Census in Mifune (Web Table 1). In addition, those lost to follow-up were more likely to be men, old, less educated, depressed at baseline, not married and have lower scores of social capital, compared to those who completed the two waves of survey (Web Table 1). However, the response rate of 71.6% in the baseline survey and the follow-up rate of 63.6% were comparable to or even higher than those in similar studies involving community-dwelling older adults (40). Second, simultaneity bias (i.e., changes in social capital were influenced by the onset of mental disorders) might have occurred, given that those who were affected by the disaster and were depressed might have perceived themselves as having inadequate social capital. Nevertheless, the community-level variables are less subject to simultaneity bias compared to the individual-level variables, because individual responses were aggregated to school districts. Third, our mental health outcomes were self-reported and could

cause measurement errors. Even so, we used a psychometrically validated questionnaire, which was well-designed for use in the Japanese older population (11). Fourth, we studied a specific earthquake in Japan, and thus the generalizability of the findings to other types of disaster and other regions might be limited.

In conclusion, for women, we found that pre-disaster social cohesion at community level was negatively associated with the risk of MDE, while its post-disaster decline elevated the risk. In contrast to social cohesion, higher levels of social participation at community level were positively associated with the risk of MDE among women. Hence, policymakers may encourage victims to participate in social activities, but they should carefully consider whether some residents had been left behind. Men were less likely to be affected by community-level social capital. Policymakers should pay attention to gender differences and the types of social capital when they leverage social capital for recovery from disasters.

ACKNOWLEDGMENTS

Author Affiliations: Department of Health Education and Health Sociology, The University of Tokyo, Bunkyo-ku, Tokyo, Japan (Koryu Sato, Airi Amemiya, Maho Haseda, Mariko Kanamori, and Naoki Kondo); Department of Health and Social Behavior, The University of Tokyo, Bunkyo-ku, Tokyo, Japan (Daisuke Takagi and Naoki Kondo); Department of Social Preventive Medical Sciences, Center for Preventive Medical Sciences, Chiba University, Chiba City, Chiba, Japan (Katsunori Kondo); and Department of Gerontological Evaluation, Center for Gerontology and Social Science, National Center for Geriatrics and Gerontology, Obu City, Aichi, Japan (Katsunori Kondo).

This study used data from JAGES (the Japan Gerontological Evaluation Study), which was supported by JSPS (Japan Society for the Promotion of Science), KAKENHI Grant Number

(JP15H01972), Health Labour Sciences Research Grant (H28-Choju-Ippan-002, H29-Chikyuukibo-Ippan-001, H30-Junkankitou-Ippan-004, 19FA1012, 19FA2001), Japan Agency for Medical Research and Development (AMED) (JP17dk0110017, JP18dk0110027, JP18ls0110002, JP18le0110009, JP19dk0110034, JP19dk0110037), and the Research Funding for Longevity Sciences from National Center for Geriatrics and Gerontology (29-42). The views and opinions expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the respective funding organizations and other organizations to which the authors belong. The funding sources had no role in study design, data collection and analysis, decision to publish, or preparation of the article. Airi Amemiya and Mariko Kanamori are Research Fellows of JSPS.

We appreciate the support and cooperation of the staff of Mifune town.

Conflict of interest: none declared.

REFERENCES

1. Parker G, Lie D, Siskind DJ, et al. Mental health implications for older adults after natural disasters - a systematic review and meta-analysis. *Int Psychogeriatr*. 2016;28(1):11–20.

2. Kawachi I, Berkman LF. Social capital, social cohesion, and health. In: Berkman LF, Kawachi I, Glymour MM, eds. *Social Epidemiology*. New York, NY: Oxford University Press; 2014:290–319.

3. Noel P, Cork C, White RG. Social Capital and Mental Health in Post-Disaster/Conflict Contexts: A Systematic Review. *Disaster Med Public Health Prep*. 2018;12(6):791–802.

4. Norris FH, Friedman MJ, Watson PJ, et al. 60,000 disaster victims speak: Part I. An empirical review of the empirical literature, 1981-2001. *Psychiatry*. 2002;65(3):207–239.

5. Tootle DM. Disaster Recovery in Rural Communities: A Case Study of Southwest Louisiana. *Southern Rural Sociology*. 2007;22(2):6–27.

6. De Alessi L. Toward an Analysis of Postdisaster Cooperation. *The American Economic Review*. 1975;65(1):127–138.

7. Solnit R. A Paradise Built in Hell: The Extraordinary Communities That Arise in Disaster. New York: Viking; 2009.

8. Fire and Disaster Management Agency. *Earthquake with seismic origin in the Kumamoto district, Kumamoto Prefecture (Report No. 120, Updated October 15, 2018).* Fire and Disaster Management Agency; 2016. http://www.fdma.go.jp/bn/2016/detail/960.html. Accessed February 13, 2019.

9. World Health Organization. *Advancing universal health coverage through knowledge translation for healthy ageing: lessons learnt from the Japan gerontological evaluation study*. Kondo K, Rosenberg M: World Health Organization; 2018. https://apps.who.int/iris/handle/10665/279010. Accessed April 18, 2019.

10. Houde SC, Gautam R, Kai I. Long-term care insurance in Japan: implications for U.S. long-term care policy. *J Gerontol Nurs*. 2007;33(1):7–13.

11. Fujii S, Kato H, Maeda K. A simple interview-format screening measure for disaster mental health: an instrument newly developed after the 1995 Great Hanshin Earthquake in Japan--the Screening Questionnaire for Disaster Mental Health (SQD). *Kobe J Med Sci*. 2008;53(6):375–385.

12. Blake DD, Weathers FW, Nagy LM, et al. The development of a Clinician-Administered PTSD Scale. *J Trauma Stress*. 1995;8(1):75–90.

13. Spitzer RL, Williams JB, Gibbon M, et al. The Structured Clinical Interview for DSM-III-R. Washington, DC: American Psychiatric Press; 1990.

14. Burke WJ, Roccaforte WH, Wengel SP. The Short Form of the Geriatric Depression Scale: A Comparison With the 30-Item Form. *Journal of Geriatric Psychiatry and Neurology*. 1991;4(3):173–178.

15. Hikichi H, Aida J, Tsuboya T, et al. Can Community Social Cohesion Prevent Posttraumatic Stress Disorder in the Aftermath of a Disaster? A Natural Experiment From the 2011 Tohoku Earthquake and Tsunami. *Am. J. Epidemiol.* 2016;183(10):902–910.

16. Hikichi H, Sawada Y, Tsuboya T, et al. Residential relocation and change in social capital: A natural experiment from the 2011 Great East Japan Earthquake and Tsunami. *Science Advances*. 2017;3(7):e1700426.

17. Hikichi H, Aida J, Matsuyama Y, et al. Community-level social capital and cognitive decline after a natural disaster: A natural experiment from the 2011 Great East Japan Earthquake and Tsunami. *Social Science & Medicine* [available online ahead of print September 28, 2018]. https://doi.org/10.1016/j.socscimed.2018.09.057.

18. Lowe SR, Sampson L, Gruebner O, et al. Psychological resilience after Hurricane Sandy: the influence of individual- and community-level factors on mental health after a large-scale natural disaster. *PLoS ONE*. 2015;10(5):e0125761.

19. Haseda M, Kondo N, Takagi D, et al. Community social capital and inequality in depressive symptoms among older Japanese adults: A multilevel study. *Health Place*. 2018;52:8–17.

20. Yamaguchi M, Inoue Y, Shinozaki T, et al. Community Social Capital and Depressive Symptoms Among Older People in Japan: A Multilevel Longitudinal Study. *J Epidemiol*. 2019;29(10):363–369.

21. Zou G. A Modified Poisson Regression Approach to Prospective Studies with Binary Data. *Am J Epidemiol*. 2004;159(7):702–706.

22. Newsom JT, Jones RN, Hofer SM, eds. Longitudinal data analysis : a practical guide for researchers in aging, health, and social sciences. New York: Routledge; 2012 391 p.

23. Mifune Town. *Mifune Town Earthquake Reconstruction Plan*. Mifune Town; 2017.

https://www.town.mifune.kumamoto.jp/common/UploadFileOutput.ashx?c_id=3&id=4587&sub_id=1&flid=160. Accessed July 12, 2019.

24. 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.

25. Yasui E. *Community vulnerability and capacity in post-disaster recovery: the cases of Mano and Mikura neighbourhoods in the wake of the 1995 Kobe earthquake* [dissertation]. Vancouver, BC: University of British Columbia; 2007.

26. Sorensen A. Changing Governance of Shared Spaces: Machizukuri in historical institutional perspective. In: Sorensen A, Funck C, eds. *Living Cities in Japan: Citizens' Movements, Machizukuri and Local Environments*. London, United Kingdom: Routledge; 2007:56–90.

27. Harpham T, Grant E, Thomas E. Measuring social capital within health surveys: key issues. *Health Policy Plan*. 2002;17(1):106–111.

28. De Silva MJ, McKenzie K, Harpham T, et al. Social capital and mental illness: a systematic review. *J Epidemiol Community Health*. 2005;59(8):619–627.

29. Ehsan AM, De Silva MJ. Social capital and common mental disorder: a systematic review. *J Epidemiol Community Health*. 2015;69(10):1021–1028.

30. De Silva MJ, Huttly SR, Harpham T, et al. Social capital and mental health: a comparative analysis of four low income countries. *Soc Sci Med*. 2007;64(1):5–20.

31. Mitchell CU, LaGory M. Social Capital and Mental Distress in an Impoverished Community. *City & Community*. 2002;1(2):199–222.

32. Thuy NTM, Berry HL. Social capital and mental health among mothers in Vietnam who have children with disabilities. *Glob Health Action*. 2013;6.

33. Kawachi I, Subramanian SV, Kim D. Social Capital and Health: a decade of progress and beyond. In: Kawachi I, Subramanian SV, Kim D, eds. *Social Capital and Health*. New York, NY: Springer New York; 2008 (Accessed August 23, 2019):1–26.(https://doi.org/10.1007/978-0-387-71311-3_1). (Accessed August 23, 2019)

34. Kawachi I, Subramanian SV. Measuring and modeling the social and geographic context of trauma: a multilevel modeling approach. *J Trauma Stress*. 2006;19(2):195–203.

35. Lowe SR, Joshi S, Pietrzak RH, et al. Mental health and general wellness in the aftermath of

Hurricane Ike. *Soc Sci Med*. 2015;124:162–170.

36. Wind TR, Komproe IH. The mechanisms that associate community social capital with post-disaster mental health: a multilevel model. *Soc Sci Med*. 2012;75(9):1715–1720.

37. Antonucci TC. A life-span view of women's social relations. In: Turner BF, Troll LE, eds. *Women growing older: Psychological perspectives*. Thousand Oaks, CA: Sage Publications, Inc; 1994:239–269.

38. Carr VJ, Lewin TJ, Webster RA, et al. Psychosocial sequelae of the 1989 Newcastle earthquake: II. Exposure and morbidity profiles during the first 2 years post-disaster. *Psychol Med*. 1997;27(1):167–178.

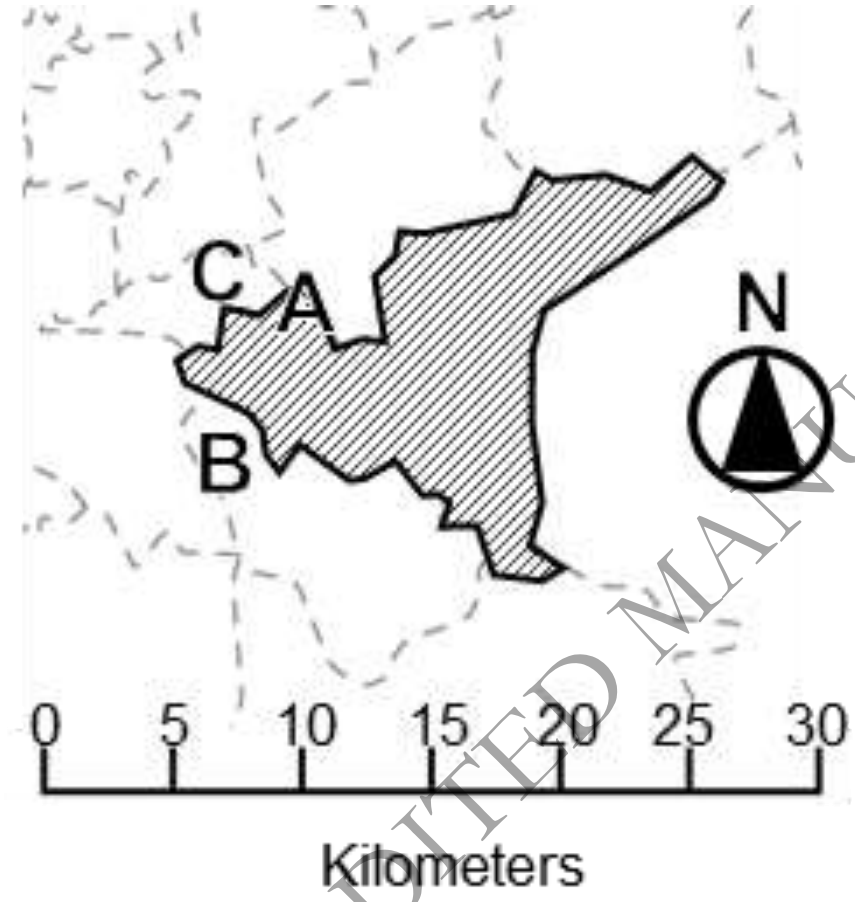
39. Jin Y, Li J. Prospective Study of Posttraumatic Stress in Adolescents 6 and 24 Months After the 2010 Yushu Earthquake in China. *J. Nerv. Ment. Dis.* 2015;203(9):679–683.

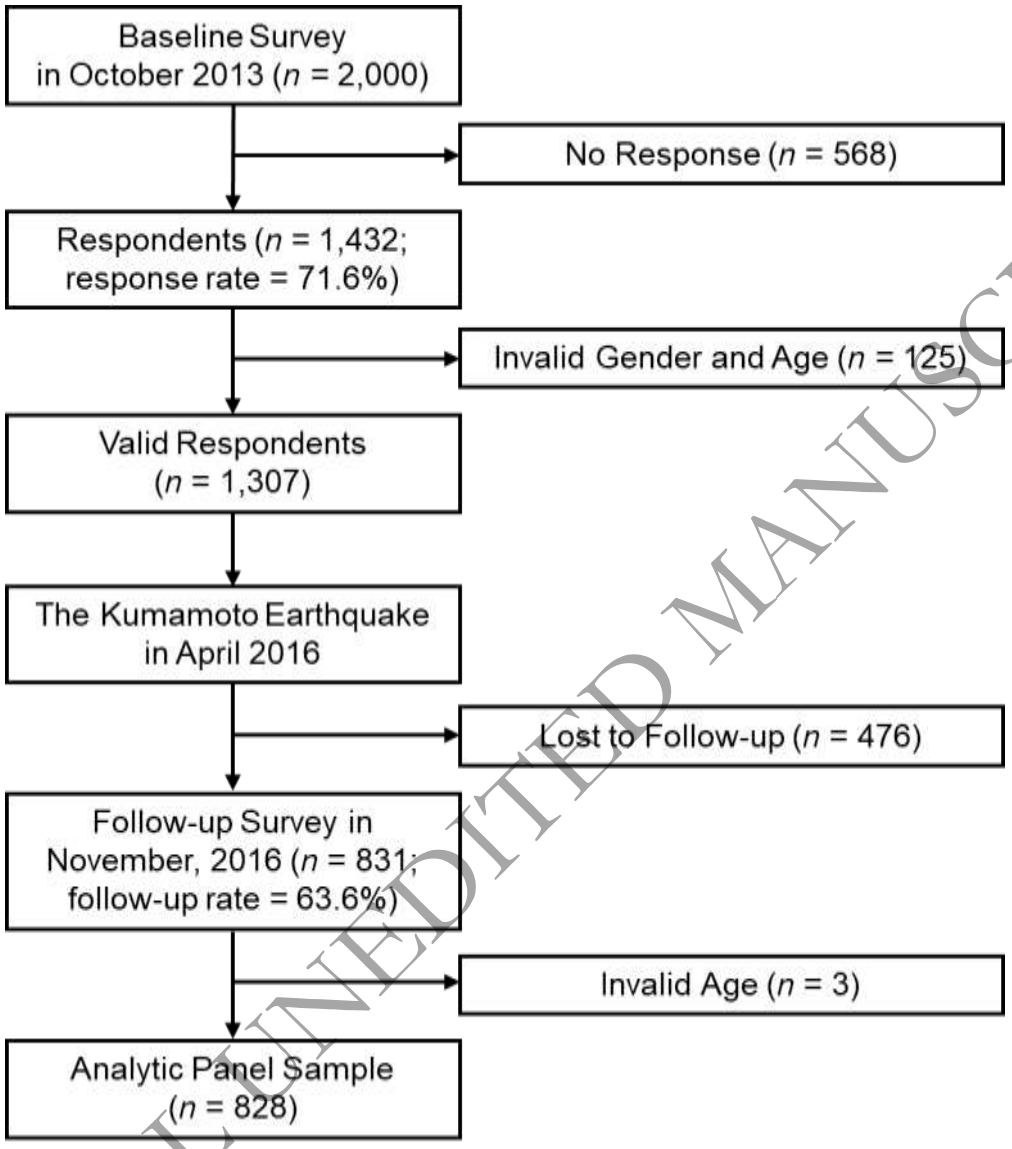
40. Santos-Eggimann B, Cuénoud P, Spagnoli J, et al. Prevalence of Frailty in Middle-Aged and Older Community-Dwelling Europeans Living in 10 Countries. *J Gerontol A Biol Sci Med Sci*. 2009;64A(6):675–681.

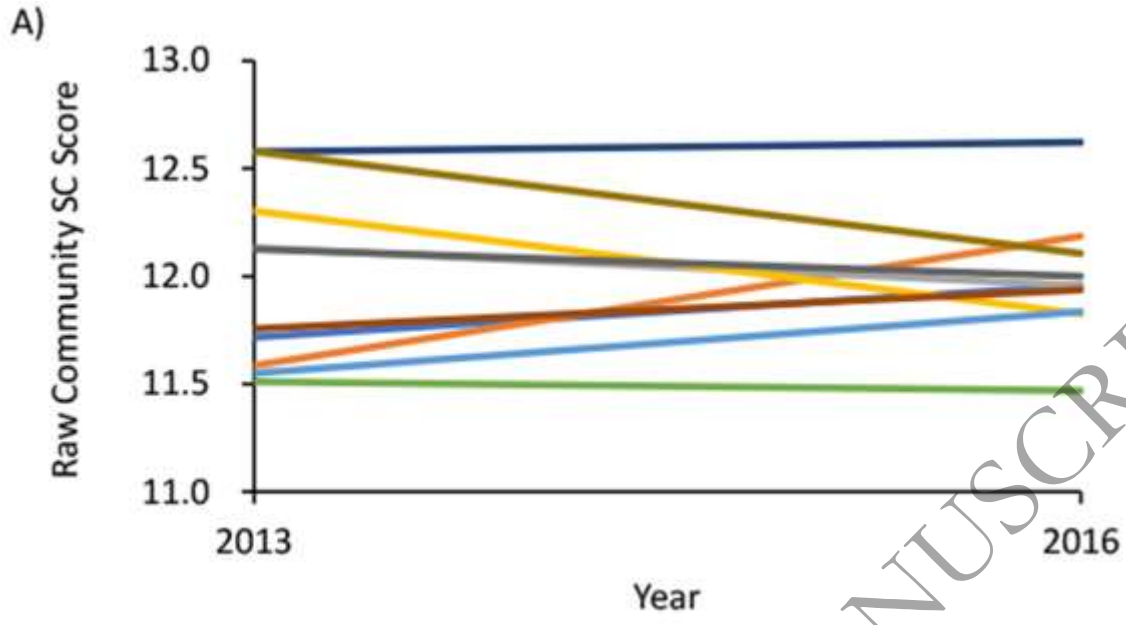
Figure 1: Map of Mifune Town and the 2016 Kumamoto Earthquake, Mifune, Japan, 2013-16. A is the epicenter of an earthquake with a magnitude of 6.2, which occurred at 9:26pm on April 14; B is the epicenter of an earthquake with a magnitude of 6.0, which occurred at 12:03am on April 15; and C is the epicenter of an earthquake with a magnitude of 7.0, which occurred at 1:25am on April 16.

Figure 2: Flowchart of the Analytic Sample, Mifune, Japan, 2013-16.

Figure 3: Changes in the Scores of Community Social Capital, Mifune, Japan, 2013-16. Panel A depicts changes in the community-level score of social cohesion, while Panel B depicts that of informal socializing and social participation. The number of participants within each area is the following: Area A: n = 229; Area B: n = 70; Area C: n = 23; Area D: n = 119; Area E: n = 91; Area F: n = 143; Area G: n = 45; Area H: n = 49; Area I: n = 40; Area J: n = 19. Abbreviation: SC: social capital.







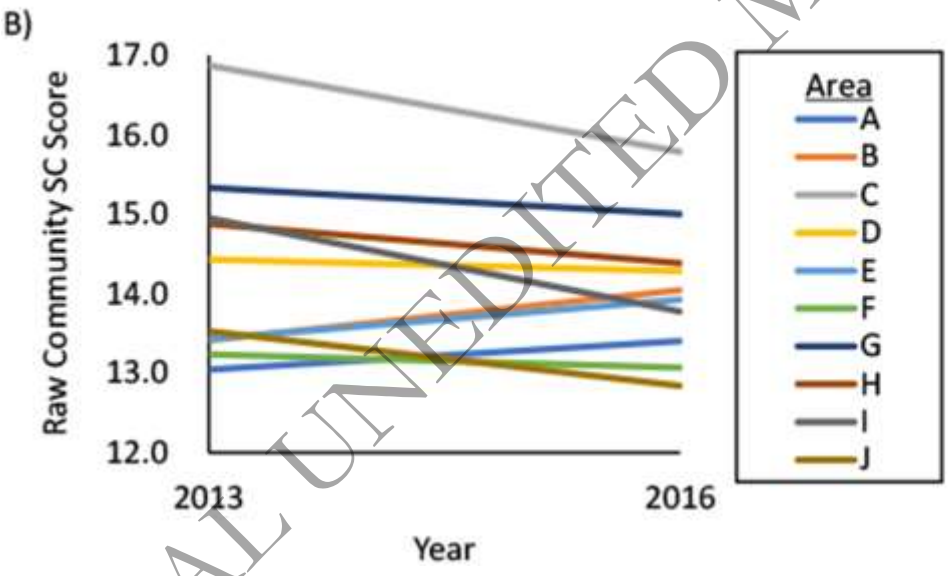


Table 1. Characteristics of the participants (N=828), Mifune, Japan, 2013-16 [a]

Characteristics	Baseline (2013)			Follow-up (2016)		
	n	%	Mean (SD)	n	%	Mean (SD)
Men	361	43.6				
Age						
65-69	230	27.8				
70-74	259	31.3				
75-79	173	20.9				
80-84	112	13.5				
≥85	54	6.5				
Education [b]						
Low (≤9 years)	347	41.9				
Middle (10-12 years)	341	41.2				
High (≥13 years)	139	16.8				
Low household income	527	63.7				
Living alone	97	11.7				
No illness	119	14.3				
Depressive symptoms (GDS)						
Not depressed (>5 points)	667	80.5				
Moderately depressed (5-10 points)	134	16.2				
Depressed (≤10 points)	27	3.2				
Social cohesion			11.84 (1.98)			11.90 (2.09)
Trust			3.89 (0.76)			3.93 (0.77)
Mutual help			3.73 (0.82)			3.79 (0.85)
Community attachment			4.21 (0.81)			4.17 (0.86)
Informal socializing & social participation			13.79 (5.10)			13.80 (4.92)
Frequency meeting with friends			4.17 (1.59)			4.03 (1.57)
Number of friends			3.88 (1.25)			3.78 (1.24)
Sports groups			2.90 (2.07)			3.08 (2.15)
Hobby groups			2.84 (1.99)			2.91 (2.02)
Having housing damage				368	44.5	
Moved due to the earthquake				156	18.8	
MDE				63	7.6	
PTSD				138	16.7	

Abbreviations: SD, standard deviation; GDS, Geriatric Depression Scale; MDE, major depressive episode; PTSD, posttraumatic stress disorder.

[a] Imputed data is used.

[b] Since estimation sample varies across imputations, the total of subgroups is not equal to 828.

Table 2. Associations of social capital with the risks of mental disorders, Mifune, Japan, 2013-16

Variable	*Major Depressive Episode*							
	Model 1 [a]				Model 2 [b]			
	RR	SE	95% CI	*P* Value	RR	SE	95% CI	*P* Value
Social cohesion								
Individual-level [c]	0.86	0.11	0.68, 1.09	0.21	0.79	0.11	0.60, 1.04	0.09
ΔIndividual-level [d]					1.22	0.15	0.96, 1.55	0.10
Community-level [c]	0.92	0.18	0.63, 1.35	0.68	0.59	0.14	0.37, 0.95	0.03
ΔCommunity-level [d]					1.88	0.46	1.17, 3.03	0.01
Informal socializing & social participation								
Individual-level [c]	0.87	0.11	0.69, 1.11	0.26	0.80	0.12	0.60, 1.06	0.12
ΔIndividual-level [d]					1.14	0.17	0.85, 1.52	0.38
Community-level [c]	1.11	0.22	0.75, 1.64	0.59	1.58	0.41	0.94, 2.63	0.08
ΔCommunity-level [d]					0.55	0.21	0.26, 1.17	0.12
Men	0.78	0.19	0.47, 1.27	0.31	0.80	0.20	0.49, 1.32	0.39
Age [e]								
70-74	3.67	1.36	1.78, 7.60	<0.001	3.85	1.40	1.88, 7.86	<0.001
75-79	4.02	1.45	1.98, 8.17	<0.001	4.63	1.69	2.27, 9.46	<0.001
80-84	2.52	1.16	1.02, 6.23	0.046	2.92	1.30	1.22, 6.99	0.02
85-	2.43	1.57	0.68, 8.65	0.17	2.67	1.77	0.73, 9.79	0.14
Education [e]								
Low	0.90	0.34	0.43, 1.88	0.78	1.04	0.39	0.49, 2.19	0.92
Middle	0.71	0.28	0.33, 1.54	0.38	0.80	0.32	0.36, 1.76	0.57
Low household income	1.79	0.66	0.87, 3.68	0.11	1.75	0.63	0.86, 3.54	0.12
Living alone	1.47	0.49	0.77, 2.82	0.25	1.72	0.59	0.88, 3.36	0.11
No illness	0.66	0.36	0.23, 1.90	0.44	0.66	0.35	0.23, 1.85	0.43
Depressive symptoms [e]								
Moderately depressed	2.44	0.81	1.27, 4.67	0.007	2.31	0.79	1.18, 4.51	0.01
Depressed	7.24	2.69	3.50, 15.00	<0.001	6.68	2.69	3.04, 14.70	<0.001
Housing damage	2.17	0.60	1.26, 3.73	0.005	2.06	0.62	1.14, 3.73	0.02
Moving	2.01	0.56	1.17, 3.46	0.01	1.95	0.58	1.09, 3.51	0.03
Population density	1.00	0.00	1.00, 1.00	0.36	1.00	0.00	1.00, 1.00	0.78
Constant	0.00	0.00	0.00, 0.02	<0.001	0.01	0.01	0.00, 0.17	0.002
	Posttraumatic Stress Disorder							
Variable	Model 1 [f]				Model 2 [g]			
	RR	SE	95% CI	*P* Value	RR	SE	95% CI	*P* Value

Social cohesion								
Individual-level [c]	1.02	0.08	0.86, 1.20	0.86	0.99	0.09	0.83, 1.19	0.95
ΔIndividual-level [d]					1.06	0.09	0.89, 1.25	0.52
Community-level [c]	0.98	0.10	0.79, 1.21	0.84	0.85	0.12	0.64, 1.13	0.26
ΔCommunity-level [d]					1.22	0.17	0.93, 1.61	0.16
Informal socializing & social participation								
Individual-level [c]	0.89	0.07	0.77, 1.04	0.15	0.89	0.09	0.74, 1.08	0.26
ΔIndividual-level [d]					1.00	0.10	0.82, 1.21	0.96
Community-level [c]	1.06	0.13	0.83, 1.35	0.64	1.14	0.19	0.82, 1.60	0.43
ΔCommunity-level [d]					0.88	0.22	0.54, 1.42	0.60
Men	0.65	0.11	0.47, 0.90	0.009	0.65	0.11	0.47, 0.90	0.01
Age [e]								
70-74	1.04	0.22	0.69, 1.57	0.85	1.04	0.22	0.69, 1.57	0.85
75-79	1.30	0.29	0.84, 2.00	0.23	1.34	0.30	0.87, 2.07	0.18
80-84	1.13	0.30	0.68, 1.89	0.64	1.17	0.31	0.69, 1.96	0.56
85-	0.81	0.31	0.38, 1.72	0.59	0.83	0.32	0.39, 1.79	0.64
Education [e]								
Low	1.11	0.29	0.67, 1.84	0.68	1.16	0.30	0.70, 1.93	0.56
Middle	0.92	0.24	0.55, 1.53	0.75	0.93	0.25	0.56, 1.56	0.79
Low household income	1.79	0.41	1.14, 2.80	0.01	1.81	0.41	1.16, 2.83	0.01
Living alone	1.16	0.26	0.74, 1.82	0.52	1.19	0.28	0.76, 1.87	0.45
No illness	0.43	0.16	0.21, 0.88	0.02	0.43	0.15	0.21, 0.87	0.02
Depressive symptoms [e]								
Moderately depressed	1.71	0.36	1.13, 2.57	0.01	1.69	0.36	1.12, 2.57	0.01
Depressed	2.88	0.75	1.72, 4.80	<0.001	2.81	0.75	1.66, 4.75	<0.001
Housing damage	1.50	0.27	1.06, 2.12	0.02	1.46	0.26	1.02, 2.07	0.04
Moving	1.38	0.28	0.93, 2.05	0.11	1.38	0.29	0.91, 2.07	0.13
Population density	1.00	0.00	1.00, 1.00	0.72	1.00	0.00	1.00, 1.00	0.93
Constant	0.07	0.04	0.02, 0.20	<0.001	0.08	0.07	0.02, 0.39	0.002

Abbreviations: RR, relative risk; SE, standard error; CI, confidence interval; VIF, variance inflation factor; AIC, Akaike information criterion.

[a] VIF 1.20, AIC 418.2

[b] VIF 1.24, AIC 414.9

[c] the baseline score of social capital measured in 2013.

[d] a difference in the score of social capital measured in 2013 and 2016 (the score of 2013 minus that of 2016).

[e] Reference categories are '65-69' for age, 'high' for education, and 'not depressed' for depressive symptoms.

[f] VIF 1.08, AIC 756.8

[g] VIF 1.09, AIC 762.2

Table 3. Associations of social capital with the risks of mental disorders by gender, Mifune, Japan, 2013-16

Major Depressive Episode

Variable	Men (n=361)				Women (n=467)			
	RR	SE	95% CI	*P* Value	RR	SE	95% CI	*P* Value
Social cohesion								
Individual-level [a]	0.65	0.15	0.41, 1.03	0.07	0.86	0.17	0.59, 1.26	0.44
ΔIndividual-level [b]	1.40	0.25	0.98, 1.99	0.06	1.22	0.23	0.84, 1.77	0.30
Community-level [a]	0.84	0.32	0.39, 1.79	0.65	0.44	0.13	0.24, 0.78	0.006
ΔCommunity-level [b]	1.63	0.59	0.80, 3.31	0.18	2.44	0.76	1.33, 4.47	0.004
Informal socializing & social participation								
Individual-level [a]	0.98	0.23	0.63, 1.55	0.94	0.76	0.14	0.53, 1.09	0.14
ΔIndividual-level [b]	0.88	0.20	0.57, 1.37	0.58	1.35	0.26	0.93, 1.97	0.12
Community-level [a]	0.75	0.35	0.30, 1.87	0.54	2.36	0.61	1.43, 3.91	0.001
ΔCommunity-level [b]	1.06	0.54	0.39, 2.88	0.91	0.35	0.14	0.16, 0.79	0.01
Age [c]								
70-74	6.71	4.48	1.81, 24.85	0.004	3.37	1.43	1.47, 7.74	0.004
75-79	18.18	10.52	5.85, 56.53	<0.001	2.19	1.16	0.77, 6.21	0.14
80-84	5.48	4.88	0.96, 31.36	0.06	2.39	1.30	0.82, 6.95	0.11
85-	21.87	20.10	3.61, 132.51	0.001	1.34	1.27	0.21, 8.57	0.76
Education [c]								
Low	1.26	0.69	0.43, 3.69	0.67	1.45	0.97	0.39, 5.37	0.58
Middle	0.79	0.61	0.17, 3.56	0.75	1.21	0.85	0.31, 4.80	0.79
Low household income	1.45	0.78	0.51, 4.16	0.49	2.53	1.21	0.99, 6.46	0.05
Living alone	3.60	2.35	1.00, 12.93	0.049	1.73	0.80	0.70, 4.27	0.23
No illness	1.56	1.35	0.28, 8.57	0.61	0.47	0.34	0.11, 1.93	0.29
Depressive symptoms [c]								
Moderately depressed	3.88	2.17	1.30, 11.59	0.02	1.89	0.81	0.81, 4.40	0.14
Depressed	12.74	8.97	3.20, 50.68	<0.001	5.71	2.99	2.05, 15.92	0.001
Housing damage	2.12	0.87	0.95, 4.72	0.07	2.32	1.05	0.96, 5.63	0.06
Moving	1.61	0.88	0.56, 4.68	0.38	2.03	0.78	0.96, 4.30	0.06
Population density	1.00	0.00	1.00, 1.00	0.98	1.00	0.00	1.00, 1.00	0.45
Constant	0.00	0.00	0.00, 0.06	0.001	0.01	0.02	0.00, 0.47	0.02

Posttraumatic Stress Disorder

Variable	Men (n=361)				Women (n=467)			
	RR	SE	95% CI	*P* Value	RR	SE	95% CI	*P* Value
Social cohesion								

Individual-level [a]	0.89	0.13	0.66, 1.20	0.44	1.03	0.13	0.81, 1.31	0.78
ΔIndividual-level [b]	1.11	0.16	0.84, 1.47	0.44	1.06	0.12	0.85, 1.33	0.59
Community-level [a]	0.68	0.18	0.40, 1.14	0.14	0.93	0.16	0.67, 1.31	0.69
ΔCommunity-level [b]	1.57	0.37	0.98, 2.51	0.06	1.07	0.18	0.76, 1.50	0.70
Informal socializing & social participation								
Individual-level [a]	1.02	0.15	0.77, 1.35	0.90	0.88	0.12	0.68, 1.14	0.34
ΔIndividual-level [b]	0.92	0.14	0.68, 1.25	0.60	1.00	0.13	0.78, 1.29	0.98
Community-level [a]	1.05	0.36	0.53, 2.06	0.89	1.16	0.23	0.79, 1.71	0.44
ΔCommunity-level [b]	1.07	0.49	0.44, 2.64	0.88	0.87	0.24	0.51, 1.51	0.63
Age [c]								
70-74	1.16	0.50	0.50, 2.68	0.74	0.99	0.24	0.61, 1.60	0.96
75-79	2.41	0.94	1.12, 5.19	0.03	0.96	0.28	0.54, 1.71	0.89
80-84	1.72	0.84	0.67, 4.46	0.26	0.96	0.31	0.51, 1.82	0.90
85-	1.40	1.16	0.28, 7.07	0.68	0.70	0.31	0.29, 1.68	0.43
Education [c]								
Low	1.05	0.36	0.54, 2.04	0.90	1.47	0.60	0.66, 3.26	0.35
Middle	0.83	0.33	0.38, 1.82	0.65	1.17	0.47	0.53, 2.57	0.70
Low household income	2.63	1.17	1.09, 6.32	0.03	1.54	0.43	0.89, 2.66	0.12
Living alone	1.43	0.76	0.51, 4.04	0.50	1.23	0.35	0.71, 2.13	0.46
No illness	0.41	0.29	0.10, 1.62	0.20	0.44	0.19	0.19, 1.01	0.05
Depressive symptoms [c]								
Moderately depressed	2.20	0.74	1.13, 4.28	0.02	1.49	0.42	0.86, 2.59	0.16
Depressed	3.69	1.69	1.51, 9.05	0.004	2.63	0.89	1.36, 5.11	0.004
Housing damage	1.50	0.40	0.90, 2.52	0.12	1.46	0.35	0.91, 2.35	0.11
Moving	1.27	0.44	0.65, 2.50	0.49	1.39	0.36	0.83, 2.32	0.21
Population density	1.00	0.00	1.00, 1.00	0.60	1.00	0.00	1.00, 1.00	0.81
Constant	0.01	0.02	0.00, 0.24	0.004	0.10	0.10	0.02, 0.67	0.02

Abbreviations: RR, relative risk; SE, standard error; CI, confidence interval.
[a] the baseline score of social capital measured in 2013.
[b] a difference in the score of social capital measured in 2013 and 2016 (the score of 2013 minus that of 2016).
[c] Reference categories are '65-69' for age, 'high' for education, and 'not depressed' for depressive symptoms.