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Original Contribution

Can Community Social Cohesion Prevent Posttraumatic Stress Disorder in the Aftermath of a Disaster? A Natural Experiment From the 2011 Tohoku Earthquake and Tsunami

Hiroyuki Hikichi*, Jun Aida, Toru Tsuboya, Katsunori Kondo, and Ichiro Kawachi

* Correspondence to Dr. Hiroyuki Hikichi, Department of Social and Behavioral Sciences, Harvard School of Public Health, 401 Park Drive, Landmark Center 4th Floor, Boston, MA 02215 (e-mail: hikichi@hsph.harvard.edu).

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In the aftermath of a disaster, the risk of posttraumatic stress disorder (PTSD) is high. We sought to examine whether the predisaster level of community social cohesion was associated with a lower risk of PTSD after the earthquake and tsunami in Tohoku, Japan, on March 11, 2011. The baseline for our natural experiment was established in a survey of older community-dwelling adults who lived 80 kilometers west of the epicenter 7 months before the earthquake and tsunami. A follow-up survey was conducted approximately 2.5 years after the disaster. We used a spatial Durbin model to examine the association of community-level social cohesion with the individual risk of PTSD. Among our analytic sample ($n = 3,567$), 11.4% of respondents reported severe PTSD symptoms. In the spatial Durbin model, individual- and community-level social cohesion before the disaster were significantly associated with lower risks of PTSD symptoms (odds ratio = 0.87, 95% confidence interval: 0.77, 0.98 and odds ratio = 0.75, 95% confidence interval: 0.63, 0.90, respectively), even after adjustment for depression symptoms at baseline and experiences during the disaster (including loss of loved ones, housing damage, and interruption of access to health care). Community-level social cohesion strengthens the resilience of community residents in the aftermath of a disaster.

community social cohesion; disaster; disaster resilience; Japan; posttraumatic stress disorder; spatial Durbin model

Abbreviations: CI, confidence interval; OR, odds ratio; PTSD, posttraumatic stress disorder.

The worldwide frequency of natural disasters has increased over time. Older individuals are particularly vulnerable in the aftermath of natural disasters. For example, more than two-thirds of the victims of the 1995 heat wave in Chicago, Illinois, were elderly (1). Similarly, more than 70% of individuals who lost their lives in Hurricane Katrina in New Orleans, Louisiana, were older than 60 years of age (2). In the 2011 earthquake and subsequent tsunami in Tohoku, Japan (also referred to as the Great East Japan earthquake and tsunami), more than 65% of individuals who died were older than 60 years of age (3).

The human toll of a disaster extends beyond the immediate damage caused by the events (e.g., drowning in a tsunami). Survivors frequently suffer from posttraumatic stress disorder (PTSD). Symptoms can be highly disruptive to daily functioning and include intrusive thoughts, flashbacks, nightmares, numbing, and hyperarousal (anger, irritability, or difficulty concentrating) (4). PTSD is also associated with suicidal ideation

and attempted suicide (5). In the case of older people, PTSD can also hasten the decline of cognitive function, particularly in the areas of processing speed, learning, memory, and executive functioning (6). PTSD tends to be associated with prolonged suffering after the traumatic event. For example, 30.3% of survey respondents reported persistent PTSD symptoms as a result of an earthquake in Italy that occurred more than a decade ago (7).

Given the substantial adverse influence of PTSD on victims' lives, a priority in disaster research is to understand the factors that predict its onset, severity, and persistence. There is considerable heterogeneity in the incidence of PTSD; individuals exposed to the same traumatic event can exhibit differing risks of PTSD symptoms depending on their genetic constitutions and background characteristics (8). Data from meta-analyses show that the presence of social support (e.g., the ability to turn to others in the network for emotional

sustenance) is an important protective factor in preventing the onset of PTSD (9, 10).

However, between-individual variation in the ability to access social support cannot adequately explain the observed community-level variations in PTSD (11). To account for these community-level variations, we need to focus on community-level protective factors for PTSD onset. This perspective has been adopted in relatively few studies.

In the present study, we focused on the role of community social cohesion as a protective influence (net of individual characteristics) in preventing PTSD symptoms. Community social cohesion is defined as the extent of social connectedness and solidarity among groups in a society (12). The health-relevant resources that residents can access through their social connections within the community include the exchange of information (e.g., where to obtain emergency assistance), instrumental support (e.g., water, shelter) (13), and emotional support (14). Some researchers have suggested that community social cohesion is associated with a lower incidence of PTSD (11, 15). However, previous findings are prone to recall bias because the information about community cohesion was gathered in the aftermath of a disaster. There has not yet been a study in which predisaster information about community social cohesion was used.

On March 11, 2011, the eastern part of Japan was struck by a magnitude 9.0 earthquake and an ensuing tsunami. An estimated 18,500 people lost their lives in the disaster (16), and approximately 345,000 people were displaced because of damage to or loss of housing (17). In the present study, we leveraged a unique natural experiment to examine the influence of community social cohesion on the incidence of PTSD among survivors. During the summer of 2010 (7 months before the Tohoku earthquake and tsunami), we completed the baseline survey of a nationwide cohort study in Japan, the original purpose of which was to examine community-level influences on healthy aging. The baseline surveys included a detailed assessment of social cohesion in the communities in which the respondents resided. One of the field sites of the cohort study happened to be located 80 kilometers west of the epicenter of the March 11 earthquake and tsunami.

Thus, we had the unique and unprecedented opportunity to examine the association between predisaster community social cohesion and the incidence of post-disaster PTSD among exposed residents. Given that results from previous studies have suggested that the prevalence of PTSD after a disaster tends to be unevenly distributed across geographical areas (13, 18), there is the potential for spatial autocorrelation that might lead to estimation bias unless accounted for in a spatial regression analysis (19). Accordingly, we conducted a spatial Durbin model to address the issue of potential autocorrelation of outcomes and to examine the potential spatial spillover association of social cohesion with an individual's risk of PTSD.

METHODS

Study participants

The Japan Gerontological Evaluation Study (JAGES) is a nationwide cohort study established in 2010 to prospectively examine individual- and community-level predictors of healthy aging. We mailed a baseline questionnaire to 169,215

community-dwelling people who were 65 years of age or older in 31 municipalities, and 112,123 individuals responded to the invitation (a response rate of 66.3%) (20).

One of the field sites of the study is based in the city of Iwanuma (the total population of which was 44,187 in 2010) (21), a coastal municipality in Miyagi Prefecture. In Iwanuma, we conducted a census of all residents who were 65 years of age or older in August 2010 ($n = 8,576$), using the official residential register (*koseki touhon*) provided by the city town hall. In the survey, we inquired about personal characteristics, as well as residents' perceptions of social cohesion in their communities. The response rate to the baseline survey was 59.0% ($n = 5,058$), which was comparable to those in other surveys of community-dwelling residents.

The Iwanuma local government divides the municipality into 99 smaller communities called *gyousei-ku*. These administrative units (average population = 36) were judged to be suitable for the purposes of defining a community in our study because they form the basis on which residents were organized for conducting disaster response drills before the earthquake and tsunami (22).

The Tohoku earthquake and tsunami struck on March 11, 2011, seven months after our cohort baseline was established. Iwanuma is located approximately 80 kilometers west of the earthquake epicenter, so it was in the direct line of the tsunami. The tsunami killed 180 residents (out of a total of 44,814) and inundated 48% of the land area (Figure 1).

Approximately 2.5 years after the disaster (starting in October 2013), we carried out a follow-up survey among the survivors. In the survey, we gathered information about people's personal experiences during and after the disaster and their symptoms of PTSD. Informed consent was obtained at the time of data collection. A detailed flow chart showing the establishment of the analytic sample is presented in Figure 2. Of the 4,380 eligible participants from the baseline survey, we managed to recontact 3,594 individuals (for a follow-up rate of 82.1%). Our analytic sample comprised 3,567 persons because of incompletely signed informed consent forms and missing responses to questions about sex and age (Figure 2). The survey protocol was reviewed and approved by the human-subjects committee of the Harvard T.H. Chan School of Public Health, as well as the human subjects committees of Tohoku University, Nihon Fukushi University, and Chiba University.

Outcome variable

Our primary outcome was PTSD symptomatology, which was assessed using the Screening Questionnaire for Disaster-Related Mental Health (23), originally developed and psychometrically validated by a team of Japanese researchers in the aftermath of the Hanshin-Awaji earthquake in 1995. The instrument was specifically designed for use in older individuals and has been psychometrically validated against the Japanese-language version of the Clinician Administered PTSD Scale (24), as well as the Impact of Event Scale-Revised, Japanese version (25). The scale is made up of 9 items, with the following predefined cutoff points for PTSD symptomatology: slightly affected (0–3 point), moderately affected (4–5 point), and severely affected (6–9 point). In the present study, we categorized the response scores into the above 3 risk levels.

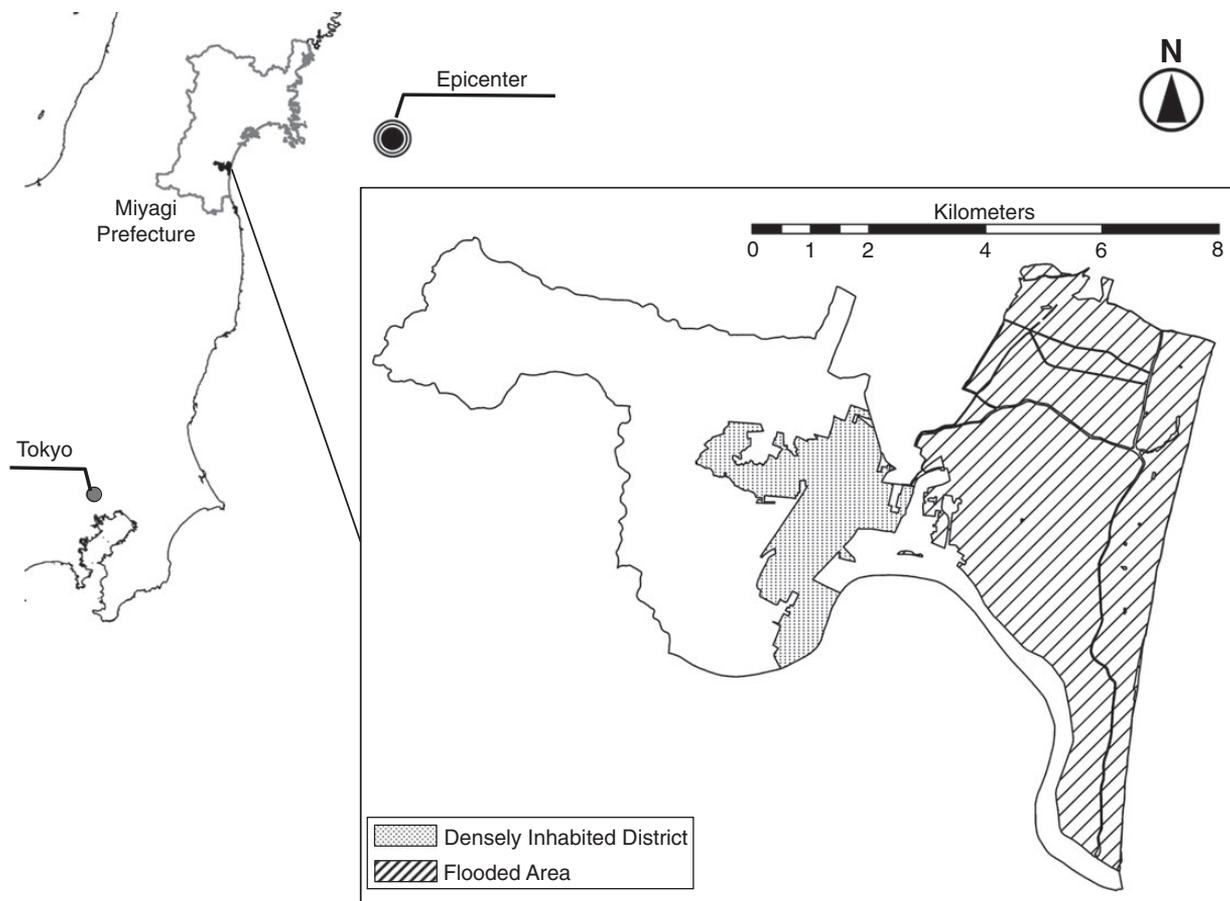


Figure 1. Map of Iwanuma, in which 187 people died or are missing, 5,428 buildings were damaged, and 48% of the area was flooded, Japan, 2010.

Explanatory variable

Our primary exposure variable of interest was community social cohesion that existed prior to the damage and disruption caused by the earthquake and tsunami. Social cohesion was assessed based on answers to questionnaire items about residents' perceptions of trust in the community, levels of mutual help, and community attachment (12). These factors were evaluated using the questions "Do you think that people living in your community can be trusted in general?" (trust); "Do you think people living in your community try to help others in most situations?" (mutual help); and "How attached are you to the community in which you live?" (community attachment). Responses were ordered along a 5-point Likert scale, with 1 indicating not at all and 5 indicating very much. The overall community cohesion scale was calculated as an arithmetic mean of responses to the 3 items (range, 1–5), with higher scores indicating higher levels of community social cohesion.

We also inquired about personal experiences of damage in the earthquake and tsunami, that is, damage or loss of housing, as well as loss of relatives or friends. The question about damage to housing is based on the official local government criteria for the purposes of compensation. A technical officer surveyed the property damage and the local government certificated the result.

The damage caused by the earthquake and tsunami tended to be localized based on the firmness of the ground soil (26) and the distance from the epicenter and coast (27). In turn, the extent of the damage to the community correlated with the overall risk of PTSD (18). In our spatial Durbin models, we therefore created within each of the 99 communities spatial lag variables for community housing damage, loss of lives, and predisaster social cohesion.

A spatial lag variable is defined as the weighted average of observations for the variable over neighboring units (28). It can be illustrated by the equation for the spatial autoregressive model that takes into account spatial autocorrelation in the dependent variable and spatially lagged dependent variable, as follows:

$$y_i = \lambda \sum_{j=1}^n w_{ij} y_j + \varepsilon_i, \quad i = 1, \dots, n,$$

where y_i denotes the dependent variable corresponding to unit i , the w_{ij} are spatial weights, ε_i is a disturbance term, and λ is the spatial autoregressive coefficient. The weighted average $\sum_{j=1}^n w_{ij} y_j$ represents the spatial lag variable (28).

We created the spatial lag variables using the Stata command `spmat` (28). This command locates each respondent in

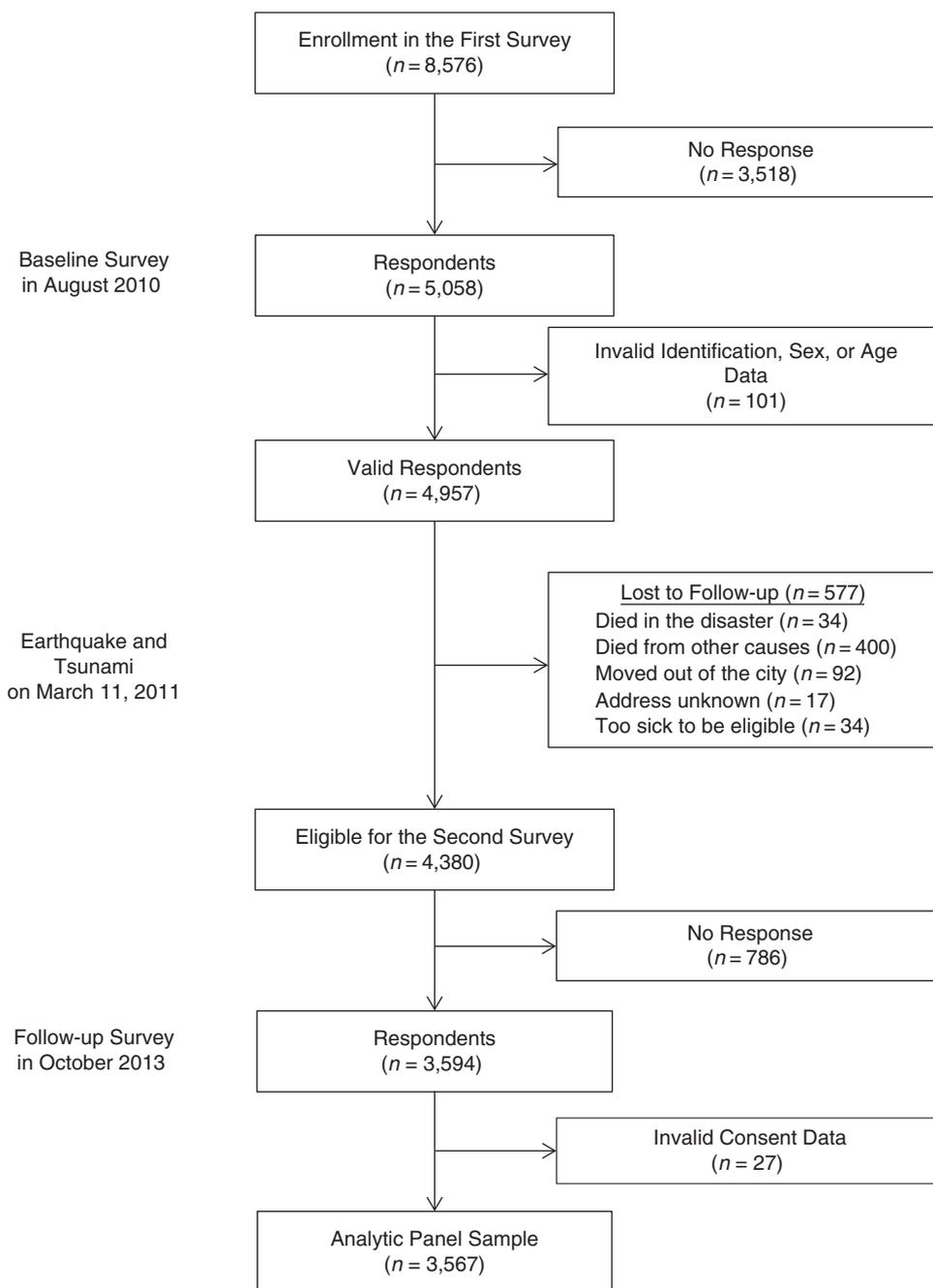


Figure 2. Flow chart for the analytic panel sample, Iwanuma, Japan, 2010–2013. The response rate in the first survey was 59.0%, and the follow-up rate in second survey was 82.1%.

a q -dimensional space (spatial weighting matrix), which is determined by the inverse distance among respondents based on latitude and longitude of geographic residence within each community (28). The distance between the 2 closest respondents in our sample was 0.003 kilometers (1/336.7878), and that between the 2 most distant respondents was 2.477 kilometers (1/0.4037). The number of survey respondents living in the 99 communities varied from 4 to 135 (mean = 36; median, 49).

Covariates

We selected as potential confounding variables sex (29), age (30), educational attainment (31), equalized income (32), depressive symptoms (defined using the Geriatric Depression Scale Short Form) (9) at the baseline survey, and interruption of access to care provided by internal medicine and psychiatry doctors just after the disaster. Age was categorized as 65–

74 years or 75 years or older. Educational attainment was categorized as 9 years or fewer versus 10 years or more. Household income was equalized by the square root of the number of household members and grouped as 2 million Japanese yen or more versus 1.99 million Japanese yen or less. Depressive symptoms were categorized as low risk (4 points or fewer) and high risk (5 points or more) (33).

We also created spatial lag variables for community educational attainment, equalized income, and the outcome (PTSD symptoms). Socioeconomically disadvantaged communities may be more severely affected by disasters because of differences in the quality of housing or because they are closer to the hazard zone in disasters (34), and the same communities may also have a higher prevalence of PTSD (18). Thus, it was important to control for potential confounding by these spatially lagged variables. In addition, there may be spatial clustering of PTSD, so it was important to control for spatial autocorrelation by creating a spatial lag variable for the dependent variable. We also used both variables in the same model to examine the direct association of each with risk of PTSD.

Statistical analysis

In the present study, we used the spatial Durbin model (19) to capture the spatial spillover association of community social cohesion and to control for spatial autocorrelation of PTSD symptoms. This approach assumes that an individual's risk of PTSD is influenced by the responses of his or her neighbors in proportion to their residential proximity to each other.

The spatial Durbin model is represented by the following equation (19):

$$y = \rho W y + X \beta_1 + W X \beta_2 + \varepsilon,$$

where ρ is the spatial autoregression parameter representing the association of PTSD among neighbors, with the individual's risk of PTSD (y) weighted by a matrix (W) of the inverse of distances between each individual and every other neighbor. β_1 is the regression coefficient for individual-level covariates, and β_2 is the regression coefficient for community-level variables using the weighted matrix (W). We used an ordered logistic regression model because our outcome was PTSD symptoms categorized into 3 levels of severity. To address potential bias due to missing data, we used multiple imputation with the Markov chain Monte Carlo method assuming missingness at random. We created 5 imputed data sets and spatial lag variables in each data set. We then utilized ordered logistic regression that included the spatial lag variables and combined each result using the Stata command `mi estimate`. Analyses were performed using STATA, version 14.0 (StataCorp LP, College Station, Texas).

RESULTS

Table 1 presents the baseline characteristics of the individuals in our sample. Women made up 56.5% of respondents, and this proportion was very close to that in the actual census of older residents in Iwanuma in October, 2010 (42.8% male, 57.2% female) (21). Persons between the ages of 65 and 74 years accounted for 59.6% of respondents. This is also quite

Table 1. Demographic Characteristics of Analytic Sample, Iwanuma, Japan, 2010–2013

Characteristic	No.	%	Mean (SD)
Sex	3,567		
Male	1,552	43.5	
Female	2,015	56.5	
Age, years	3,567		
65–74	2,127	59.6	
≥75	1,440	40.4	
Educational attainment, years	3,429		
≥10	2,199	64.1	
≤9	1,230	35.9	
Equalized income, Japanese yen	2,911		
≥2 million	1,489	51.2	
≤1.99 million	1,422	48.8	
Depression score, points ^a	3,074		
≥5	984	32.0	
≤4	2,090	68.0	
Loss of relatives or friends	3,496		
No	2,167	62.0	
Yes	1,329	38.0	
Housing damage	3,466		
No damage	1,423	41.0	
Affected	1,496	43.2	
Minor	257	7.4	
Major	131	3.8	
Destroyed	159	4.6	
Interruption of access to internal medicine	3,439		
No	3,277	95.3	
Yes	162	4.7	
Interruption of access to psychiatry	3,439		
No	3,420	99.4	
Yes	19	0.6	
Perceived mutual help ^b	3,456		3.54 (0.83)
Trust toward community ^b	3,487		3.75 (0.77)
Community attachment ^b	3,484		4.00 (0.83)
PTSD ^c	3,348		
Slightly affected (0–3 points)	2,481	74.1	
Moderately affected (4–5 points)	486	14.5	
Severely affected (6–9 points)	381	11.4	

Abbreviations: PTSD, posttraumatic stress disorder; SD, standard deviation.

^a Measured using the Geriatric Depression Scale Short Form.

^b The range is 1 (not at all) to 5 (very much).

^c Measured using the Screening Questionnaire for Disaster-Related Mental Health.

close to the percentage in the census data (51.9% versus 48.1% ≥75 years of age) (21). A somewhat higher proportion of our respondents were married (71.4%) compared with

participants from the census data (64.7%) (35). The proportion of workers in our data (17.8%) was quite close to that the census data (17.2%) (36). These comparisons support the representativeness of our data relative to Iwanuma as a whole (also see Appendix Table 1).

Among the respondents, 38.0% reported losing loved ones (relatives or friends), whereas 59.0% reported personal damage to their property as a result of the disaster (Table 1). The proportion of respondents with severe PTSD symptoms was 11.4%, which was lower than the prevalence of 20.6% reported in a previous study of older residents affected by the 1995 Great Hanshin earthquake (also known as the Kobe earthquake) (23).

The items measuring trust, mutual help, and community attachment were averaged to create an overall social cohesion score (mean = 3.76; standard deviation, 0.67; Cronbach α = 0.77).

Table 2. Odds Ratios for the Risk of Posttraumatic Stress Disorder in the Analytic Sample (n = 3,567), Iwanuma, Japan, 2010–2013

Variable	OR	95% CI	P Value ^a
Female sex ^b	1.78	1.49, 2.12	<0.01
Age \geq 75 years ^c	1.10	0.92, 1.31	0.28
Educational attainment \leq 9 years ^d	1.01	0.84, 1.22	0.89
Equivalent income \leq 1.99 million Japanese yen ^e	1.08	0.91, 1.29	0.36
Depression score ^f \geq 5 points	2.13	1.79, 2.53	<0.01
Loss of relatives or friends ^g	1.94	1.64, 2.29	<0.01
Housing damage ^h	1.64	1.36, 1.98	<0.01
Interruption of access to internal medicine ^g	2.23	1.60, 3.10	<0.01
Interruption of access to psychiatry ^g	9.57	3.37, 27.19	<0.01
Social cohesion ^h	0.87	0.77, 0.98	0.02
Educational attainment ⁱ	1.08	0.96, 1.21	0.19
Equivalent income ⁱ	0.97	0.84, 1.11	0.66
Loss of relatives or friends ⁱ	0.95	0.85, 1.06	0.36
Housing damage ⁱ	1.96	1.04, 3.72	0.04
Social cohesion ⁱ	0.75	0.63, 0.90	<0.01
λ^j	1.40	1.22, 1.61	<0.01
Cutpoint 1 ^k	3.09	2.55, 3.64	<0.01
Cutpoint 2 ^k	4.23	3.68, 4.79	<0.01

Abbreviations: CI, confidence interval; OR, odds ratio.

^a Two-sided P values.

^b The referent was male sex.

^c The referent was age of 65–74 years.

^d The referent was \geq 10 years.

^e The referent was \geq 2 million Japanese yen.

^f Measured using the Geriatric Depression Scale Short Form. The referent was \leq 4 points.

^g The referent was no/none.

^h Continuous variable.

ⁱ Spatial lag.

^j Spatial lag of the dependent variable.

^k Estimated cutpoint for the 3 risk levels of posttraumatic stress disorder.

As shown in Table 2, the spatial Durbin model indicated that both individual- and community-level social cohesion were significantly associated with a lower risk of severe PTSD symptoms (odds ratio (OR) = 0.87, 95% confidence interval (CI): 0.77, 0.98 and OR = 0.75, 95% CI: 0.63, 0.90, respectively). As expected, loss of family/relatives or friends and housing damage at the individual level were associated with higher risks of PTSD symptoms (OR = 1.94, 95% CI: 1.64, 2.29 and OR = 1.64, 95% CI: 1.36, 1.98, respectively). In addition, interruptions of access to internal medicine and psychiatry services after the disaster were also associated with elevated PTSD symptoms (OR = 2.23, 95% CI: 1.60, 3.10 and OR = 9.57, 95% CI: 3.37, 27.19, respectively). The spatial lag variable for housing damage was also positively associated with a higher risk of PTSD (OR = 1.96, 95% CI: 1.04, 3.72). The spatial autoregression parameter for the dependent variable was also significantly associated with a higher risk of PTSD (OR = 1.40, 95% CI: 1.22, 1.61).

DISCUSSION

To our knowledge, this is the first study in which both individual- and community-level social cohesion predating a disaster have been associated with a lower risk of PTSD symptoms. The protective associations were found even after statistically controlling for personal experiences of damage from the disaster (at both the individual and community levels), as well as pre-existing mental health problems predated the disaster. The strength of the associations of individual and community social cohesion with subsequent PTSD symptoms appear to be both statistically and clinically important. For example, each 1-standard-deviation difference in community social cohesion was associated with a 17% reduction in the risk of PTSD symptoms after the disaster (for community social cohesion, standardized OR = 0.83).

In previous reports, investigators also focused on community social cohesion as a protective factor for mental health problems in the aftermath of a disaster. After the 2008 Morepeth floods in the United Kingdom (15) and the 2012 Hurricane Sandy in New York (11), researchers found that social cohesion and collective efficacy in the community were associated with lower incidence of PTSD. However, these findings were based upon retrospective recall of community conditions collected in the aftermath of disaster, and researchers were not able to prospectively evaluate the influence of predisaster community conditions on postdisaster mental health among survivors. In a 3-wave longitudinal follow-up among survivors of Hurricane Ike in the United States (2008), researchers reported that community collective efficacy was protectively associated with mental health (37). However, even in that longitudinal study, the researchers did not have access to a predisaster assessment of community collective efficacy. Our study is unique in that we were able to take advantage of a natural experiment afforded by the fact that the 2011 earthquake and tsunami happened 7 months after our baseline survey was completed.

Community-level social cohesion is theorized to promote population health by strengthening both individual and community resilience in the aftermath of disaster (11). Nakagawa and Shaw (38) found that predisaster social networks in the

community helped to explain the differential rates of community recovery after major earthquakes in Kobe, Japan (1995), and Gujarat, India (2001). Our findings suggest that social cohesion in the community contributes to the resilience of the community in the recovery process after exposure to mass trauma. Our 3-item scale of social cohesion is relatively simple to administer and may prove to be of value in disaster planning and preparedness. Mapping the variations in community cohesion may assist planners in forecasting mental health needs in the event of disaster.

There are several plausible pathways linking community social cohesion to the prevention of PTSD symptoms. Community networks function as a form of “informal insurance” among residents, enabling them to turn to each other for information and support during times of emergency (39). For example, neighbors may act as important sources of information, such as psychiatric referrals, or they may be simply there to provide a “sympathetic ear” for people dealing with loss. Residents might feel more secure as a result of knowing that they are surrounded by supportive neighbors (40). In addition, socially cohesive communities are likely to be more effective in voicing the needs of survivors to disaster relief agencies and local governments (39). Cohesive communities are more effective in mobilizing and in undertaking collective action, for example, to lobby for needed resources (such as mental health services) in the wake of disaster.

A major strength of the present study is the availability of predisaster information about community social cohesion and individual mental health conditions. Our design therefore enabled us to effectively address the problem of recall bias that occurs in most studies conducted in postdisaster settings. Another strength is our attempt to address estimation bias caused by spatial autocorrelation of the outcome.

Our study has several limitations. First, selection bias might have occurred because of the 59% response rate to the baseline survey (predating the earthquake). However, this response rate is quite comparable to (if not higher than) those in similar surveys involving community-dwelling residents. In addition, we confirmed that the demographic profile of our participants is quite similar to the rest of Iwanuma residents aged 65 years or older (Appendix Table 1). In addition, the response rate to our follow-up survey among survivors was quite high (82.1%), thanks to the exceptional tracking capabilities of the Japanese official residential registration system.

A second limitation is that PTSD symptomatology was assessed using self-reported data. Even so, our measurement tool was specifically developed and psychometrically validated for a Japanese older population based on a sample of earthquake survivors (23). Third, because both the exposure (community social cohesion) and outcome (PTSD symptoms) were assessed by self-report, our analyses could have been affected by common method bias (12). However, our spatial Durbin model is based upon other residents’ perceptions of social cohesion weighted by their geographic distance. Therefore, the possibility of common source bias is greatly reduced.

In conclusion, results from previous studies have suggested that community social cohesion is associated with the prevention of PTSD in the aftermath of a disaster. These findings, however, could have been affected by recall bias because the studies lacked predisaster information. Our study

addresses that gap and suggests that social cohesion among neighbors might help to explain the community-level variations in the occurrence of PTSD after natural disasters.

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Author affiliations: Department of Social and Behavioral Sciences, Harvard T.H. Chan School of Public Health, Boston, Massachusetts (Hiroyuki Hikichi, Ichiro Kawachi); Department of International and Community Oral Health, Graduate School of Dentistry, Tohoku University, Sendai, Japan (Jun Aida, Toru Tsuboya); and Center for Preventive Medical Sciences, Chiba University, Chiba, Japan (Katsunori Kondo).

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Conflict of interest: none declared.

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(Appendix follows)

Appendix Table 1. Comparison of Analytic Sample and Census Population Members Who Were 65 Years of Age or Older, Iwanuma, Japan, 2010

Characteristic	Analytic Sample in 2010		2010 National Census Population	
	No.	%	No.	%
Sex	3,567		8,723	
Male	1,552	43.5	3,735	42.8
Female	2,015	56.5	4,988	57.2
Age, years	3,567		8,723	
65–74	2,127	59.6	4,523	51.9
≥75	1,440	40.4	4,200	48.1
Marital status	3,444		8,686	
Married	2,460	71.4	5,618	64.7
Unmarried, widowed, or divorced	984	28.6	3,068	35.3
Employment status	3,139		8,662	
Working	560	17.8	1,493	17.2
Not working	2,579	82.2	7,169	82.8