SOCIAL SCIENCES

Residential relocation and change in social capital: A natural experiment from the 2011 Great East Japan Earthquake and Tsunami

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Social connections in the community ("social capital") represent an important source of resilience in the aftermath of major disasters. However, little is known about how residential relocation due to housing destruction affects survivors' social capital. We examined changes in social capital among survivors of the 2011 Great East Japan Earthquake and Tsunami. People who lost their homes were resettled to new locations by two primary means: (i) group relocation to public temporary trailer housing or (ii) individual relocation, in which victims moved into government-provided housing by lottery or arranged for their own accommodation (market rental housing or private purchase/new construction). The baseline for our natural experiment was established 7 months before the 11 March 2011 disaster, when we conducted a survey of older community-dwelling adults who lived 80-km west of the earthquake epicenter. Approximately 2.5 years after the disaster, the follow-up survey gathered information about personal experiences of disaster as well as health status and social capital. Among 3421 people in our study, 79 people moved via group relocation to public temporary trailer housing, whereas 96 people moved on their own. The individual fixed-effects model showed that group relocation was associated with improved informal socializing and social participation (β coefficient = 0.053, 95% confidence interval: 0.011 to 0.095). In contrast, individual relocation was associated with declining informal socializing and social participation (β coefficient = −0.039, 95% confidence interval: −0.074 to −0.003). Group relocation, as compared to individual relocation, appeared to preserve social participation and informal socializing in the community.

INTRODUCTION

The worldwide frequency of natural disasters is increasing over time (*1*). Older individuals are disproportionately affected by natural disasters. For example, in the aftermath of the 2011 Great East Japan Earthquake and Tsunami, 89% of the post-disaster–related deaths were older adults aged 65 years old or older (*2*). Older disaster-affected survivors are vulnerable to health problems, including loss of functional mobility and cognitive function. We have previously documented that older survivors of the Great East Japan Earthquake and Tsunami are particularly vulnerable to increased risk of functional disability (*3*) as well as cognitive decline (*4*). In turn, a wealth of epidemiological evidence suggests that the preservation of cognitive and physical function in older individuals is dependent on their ability to maintain social connections in the community (*5*). It is increasingly recognized that preserving social connections in the community—also referred to as "social capital"—serves as a critical ingredient in improving disaster resilience and protecting the health of older adults (*6*–*8*). According to Aldrich (*8*), communities endowed with higher stocks of social capital—that is, stronger bonds of trust between community members as well as norms of mutual assistance—are better equipped to cope with the devastating consequences of disaster.

However, at the same time, major disasters (such as earthquakes, tsunamis, hurricanes, and floodings) are frequently associated with widespread destruction of housing and forced relocation of residents, resulting in the fragmentation of communities (*9*–*11*). Assisting the victims to stay connected to their communities poses a challenge, particularly for older residents (*2*, *10*).

The few studies on the subject have yielded contradictory findings, with some reports suggesting that community social capital can be preserved or even strengthened after resettlement (*12*, *13*). Some communities faced with a major external threat demonstrate the ability to stick more closely together ("bounded solidarity"). On the other hand, involuntary residential displacement is likely to disrupt patterns of daily social interactions, thereby eroding social capital. Prospective studies that examined changes in social capital in the aftermath of disasters remain extremely scarce. Asking about pre-disaster conditions in the aftermath of a disaster is obviously subject to recall bias.

Social capital is defined as the stock and quality of social connections in the community and is divided into two separate dimensions, namely, the cognitive dimension, which refers to what residents perceive about social relations in the community (for example, the trustworthiness of their neighbors, perceived norms of mutual help, and attachment to the community), and the structural dimension, which refers to what residents actually do in their social networks (for example, informal socializing with neighbors and participation in social activities) (*14*).

Here, we took advantage of a unique "natural experiment" stemming from the 2011 Great East Japan Earthquake and Tsunami, in which an estimated 18,500 people lost their lives (*15*) and approximately 345,000 people were involuntarily displaced because of widespread sudden property destruction (*16*). Our nationwide cohort study of aging, the Japan Gerontological Evaluation Study (JAGES), was established 7 months before the disaster to examine individual and community predictors of healthy aging. One of the field sites of the cohort was Iwanuma city in Miyagi Prefecture, located approximately 80-km west of the earthquake epicenter (Fig. 1). Approximately 2.5 years after the disaster, we recontacted 3594 survivors to gather information about their disaster experiences and perceptions of social capital (Fig. 2).

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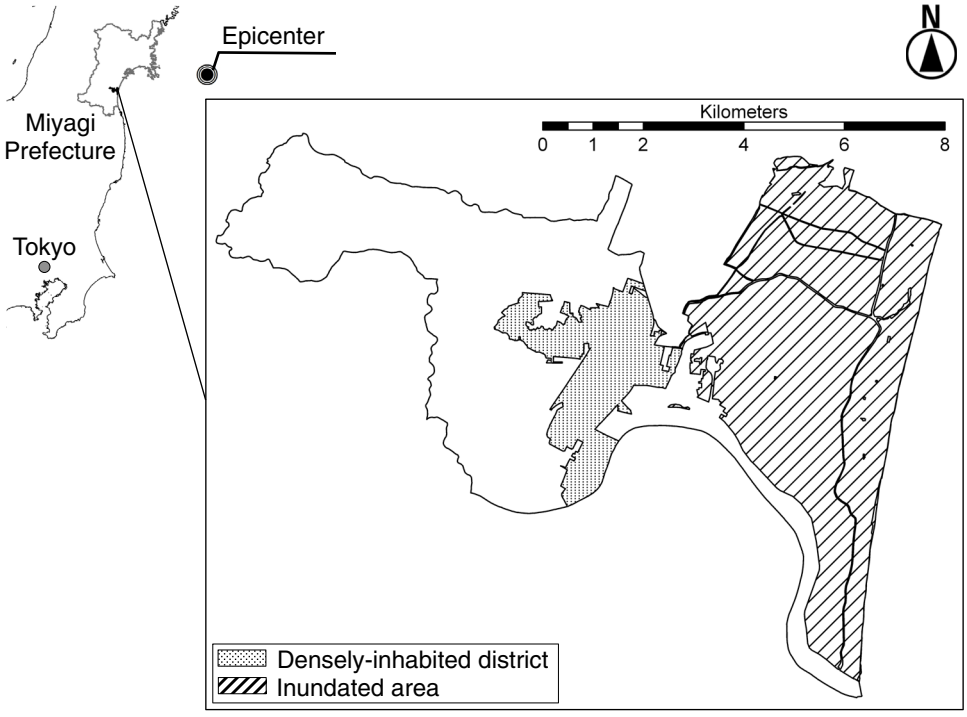

Fig. 1. Map of inundated area in Iwanuma city, Japan.

Immediately after the disaster, while survivors were still housed in emergency shelters, city officials required them to make a decision about which type of relocation to temporary housing they preferred. The two options given were (i) group relocation, in which whole communities were moved to public prefabricated temporary housing villages [kasetsu jutaku, which resembled FEMA (Federal Emergency Management Agency)–style trailer parks in the United States], or (ii) individual relocation, in which people were moved to public housing by a random lottery elected to seek housing in the open rental market, or built new homes for themselves (fig. S1). Thus, survivors could choose either option based on consideration of their situation, including family size, convenience, or impatience to get away from the crowded living conditions in the emergency shelters. Our hypothesis is that group relocation may have helped to preserve social connections in the community and thereby promoted resilience (*17*), whereas individual relocation tended to erode communality and social connections that existed before the disaster (*18*). Our unique design afforded us the opportunity to examine the association between two types of resettlement and change of social capital.

RESULTS

We compared our analytic sample with the local (pre-disaster) census data for older residents (table S1). Females made up 55.6% of all analytic samples, and this proportion is comparable to the actual census of older residents in Iwanuma city in October 2010 (male, 42.8%; female, 57.2%) (*19*). The age distribution of our sample is also close to that of the local census data except for the group aged 85 years and over (our sample, 5.0%; census data, 13.2%) (*19*). Our respondents were also somewhat more likely to be married (74.0%) compared to the census (64.7%) (*20*). However, the proportion of employed individuals in our study (18.4%) is quite close to the census data (17.2%) (*21*).

In addition, we also compared the characteristics of respondents who lived in the tsunami-inundated area (n = 523) to the corresponding local census data for older residents (table S1). The sex distribution was similar, although our analytic sample was somewhat younger than the census population. The proportion of married persons in our sample (72.3%) was similar to the census data (64.7%). These comparisons support the representativeness of our data relative to Iwanuma city as a whole for residents aged 65 years or older.

Table 1 presents the characteristics of our sample at baseline (before the disaster) and at follow-up 2.5 years after the disaster. Among the analytic samples, 5.3% of the study sample was forced to relocate, with 2.4% reporting group relocation and 2.9% reporting individual relocation after the disaster. Thirty-eight percent of respondents reported losing relatives and/or friends in the disaster. All components of social cohesion as well as informal socializing and social participation decreased during the follow-up term.

We calculated sex- and age-adjusted scores for each component of social capital at both surveys according to the type of relocation (table S2). Three years after the disaster, respondents who relocated together with the whole community showed increases in informal socializing and social participation: frequency of meeting with friends (3.93 to 4.40), numbers of friends met during the past month (3.57 to 3.58), and frequency of participating in sports clubs (1.35 to 1.46) and hobby clubs (1.62 to 1.63).

The results of the factor analysis supported our approach to creating two subscales for social capital—one representing the cognitive dimension ("social cohesion") and the other representing the structural dimension ("informal socializing and social participation"). The subscales had good internal consistency reliability, with Cronbach's α = 0.767 and 0.705, respectively (Table 2). The scores for each subdimension were calculated by summing the normalized arithmetic mean so that higher scores indicate higher levels of social capital (*22*).

As shown in Table 3, the individual fixed-effects model for the overall sample (n = 3421) showed that individual relocation was associated with decrements in social cohesion as well as informal socializing and social participation over the 3-year follow-up [β coefficient = −0.064,

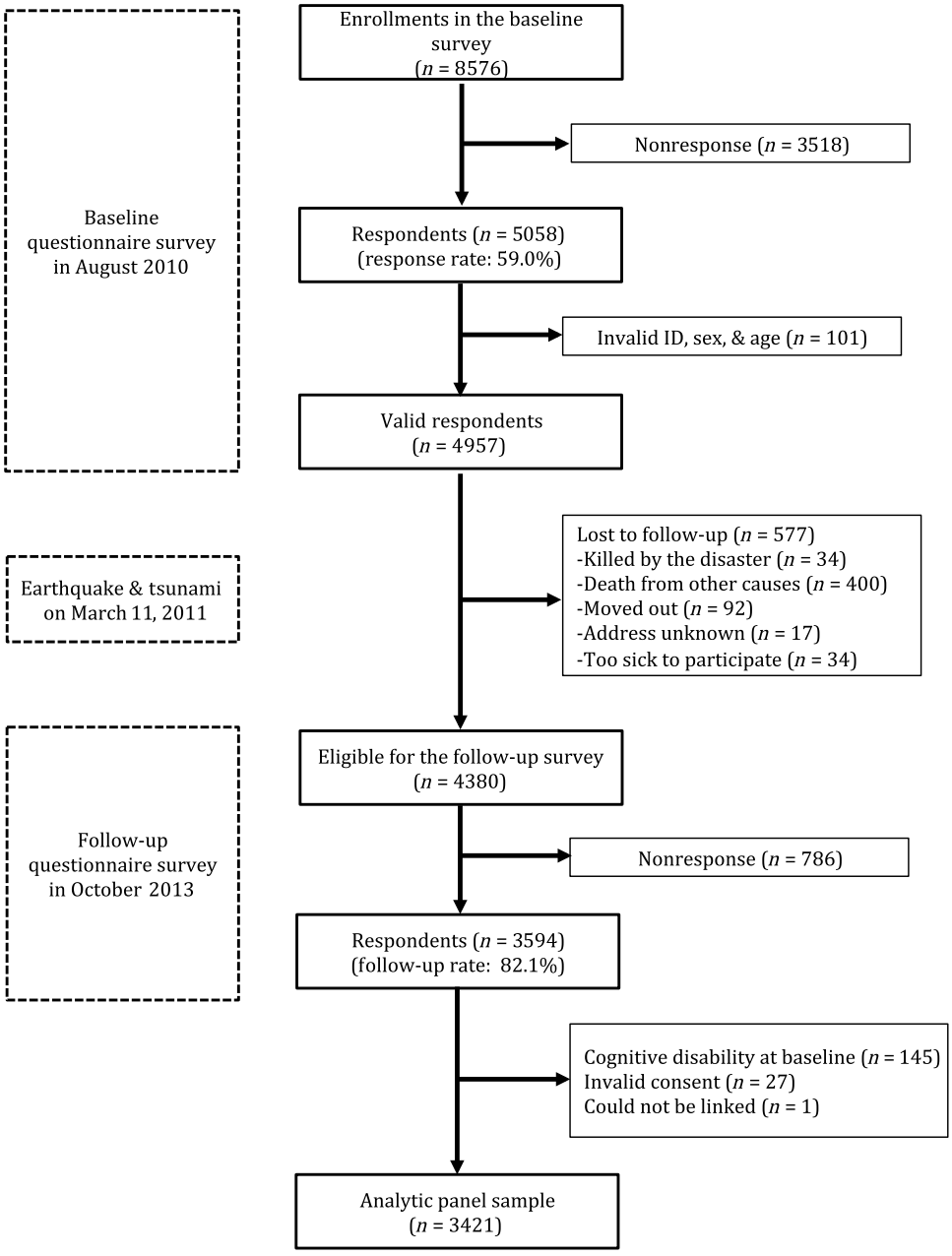

Fig. 2. Participants flow for analytic samples (*n* = 3421).

95% confidence interval (CI): −0.096 to −0.032; β coefficient = −0.039, 95% CI: −0.074 to −0.003, respectively]. Group relocation was associated with improved informal socializing and social participation (β coefficient = 0.053, 95% CI: 0.011 to 0.095), although it did not show a significant association with social cohesion (β coefficient = −0.033, 95% CI: −0.069 to 0.004).

Pre-disaster characteristics were systematically correlated with different types of resettlement and traumatic disaster experiences (for example, loss of relatives and/or friends) (table S3). To balance covariates for our natural experimental design, we conducted a subgroup analysis restricted to respondents who lived in the same tsunami-inundated area (*n* = 523), which showed statistically nonsignificant systematic correlations between personal characteristics and disaster experiences (table S4). As shown in Table 4, individual relocation was again significantly associated with decreased social cohesion (β coefficient = −0.063, 95% CI: −0.112 to −0.013) and decreased informal socializing and social participation (although the estimate was not statistically significant; β coefficient = −0.016, 95% CI: −0.064 to 0.031). In contrast, group relocation remained significantly associated with improving informal socializing and social participation (β coefficient = 0.076, 95% CI: 0.027 to 0.125).

DISCUSSION

Using a unique natural experimental design, our study demonstrates for the first time that residential relocation following a major disaster was associated with changes in levels of social capital. Individual relocation

Table 1. Characteristics of the analytic sample in baseline and follow-up survey. JPY, Japanese Yen.

	Baseline survey in August 2010				Follow-up survey in October 2013			
	*n**	%	Mean	SD	*n**	%	Mean	SD
Relocation†								
No	—	—	—	—	3125	94.7	—	—
Group relocation	—	—	—	—	79	2.4	—	—
Individual relocation	—	—	—	—	96	2.9	—	—
Total	—	—	—	—	3300	100	—	—
Loss of relatives and/or friends†								
No	—	—	—	—	2080	62.0	—	—
Yes	—	—	—	—	1277	38.0	—	—
Total	—	—	—	—	3357	100	—	—
Age								
(continuous)	3421	—	73.3	6.0	3421	—	76.5	6.0
Equivalent income								
Under 2.0 million JPY	1365	48.6	—	—	1523	52.9	—	—
2.0 million JPY and over	1442	51.4	—	—	1354	47.1	—	—
Total	2807	100	—	—	2877	100	—	—
Employment status								
Nonemployment	2465	81.6	—	—	2871	86.6	—	—
Employment	554	18.4	—	—	444	13.4	—	—
Total	3019	100	—	—	3315	100	—	—
Marital status (divorce or bereavement)								
No (married)	2404	74.0	—	—	2305	69.6	—	—
Yes	843	26.0	—	—	1005	30.4	—	—
Total	3247	100	—	—	3310	100	—	—
Living alone								
No	3028	90.9	—	—	2975	88.7	—	—
Yes	303	9.1	—	—	380	11.3	—	—
Total	3331	100	—	—	3355	100	—	—
Depressive symptoms								
Lower risk (≤4)	2054	69.6	—	—	2038	68.4	—	—
Higher risk (≥5)	899	30.4	—	—	943	31.6	—	—
Total	2953	100	—	—	2981	100	—	—
Mutual help								
1: Not at all, 5: Very much	3321	—	3.54	0.82	3346	—	3.54	0.79
Trust								
1: Not at all, 5: Very much	3352	—	3.76	0.76	3372	—	3.74	0.71

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	Baseline survey in August 2010				Follow-up survey in October 2013			
	*n**	%	Mean	SD	*n**	%	Mean	SD
Community attachment								
1: Not at all, 5: Very much	3344	—	4.00	0.82	3375	—	3.96	0.82
Frequency meeting with friends								
1: Rarely, 6: Almost everyday	3289	—	3.76	1.47	3375	—	3.66	1.55
Number of friends who met for the past month								
1: None, 5: 10 or more	3260	—	3.61	1.26	3368	—	3.45	1.34
Frequency participating to sports club								
1: None, 6: Almost everyday	2880	—	1.88	1.44	3280	—	1.81	1.43
Frequency participating to hobby club								
1: None, 6: Almost everyday	2936	—	2.28	1.46	3287	—	1.93	1.39
Sex (time-invariant variable)‡								
Male	1518	44.4	—	—	—	—	—	—
Female	1903	55.6	—	—	—	—	—	—
Total	3421	100	—	—	—	—	—	—
Educational attainment (time-invariant variable)‡								
9 years and under	1159	35.1	—	—	—	—	—	—
10 years and over	2140	64.9	—	—	—	—	—	—
Total	3299	100	—	—	—	—	—	—

*Almost all items include missing values (overall analytic sample is 3421). †Empty cells at baseline due to data taken before the disaster. ‡Empty cells at follow-up due to time-invariant variables.

Table 2. Factor structure for measurements of social capital.

Factor	Measurement	Factor loadings		Eigenvalue	Cronbach's α
		Factor 1	Factor 2		
Social cohesion	Mutual help	−0.039	0.731	1.787	0.767
	Trust	−0.030	0.771		
	Community attachment	0.104	0.564		
Informal socializing and social participation	Frequency meeting with friends	0.567	0.079	1.145	0.705
	Number of friends who met for the past month	0.592	0.061		
	Frequency participating to sports club per 1 week	0.583	−0.043		
	Frequency participating to hobby club per 1 week	0.660	−0.054		

weakened both dimensions of social capital, but group relocation strengthened informal socializing and social participation. These associations remained after statistically controlling for observed and unobserved time-invariant personal traits as well as several time-variant covariates before and after the disaster.

Our findings about forced residential relocation and its corrosive effects on social cohesion echo an earlier seminal case study by Erikson (*18*) in the aftermath of the 1972 Buffalo Creek Flood in West Virginia. In that disaster, a local dam was breached, resulting in the forced evacuation of nearly 4000 residents living in more than a dozen coal mining towns. The premise of Erikson's work is that the resettlement of survivors in trailer homes without regard to the formerly tightly knit communities resulted in a "loss of communality" and exacerbated community trauma (*18*). More recently, a cross-sectional study of 281 survivors of the 2011 Great East Japan Earthquake and Tsunami showed that survivors who were resettled into trailer housing by lottery (individual relocation) were less likely to report giving and receiving social support to and from their neighbors (*17*).

Table 3. Effects of disaster damage on social capital among all analytic samples (n = 3421).

	Outcome: Normalized social cohesion		Outcome: Normalized informal socializing and social participation	
	β Coefficient (95% CI)	*P*	β Coefficient (95% CI)	*P*
Relocation (ref. no.)				
1: Group (n = 79)	−0.033 (−0.069 to 0.004)	0.079	0.053 (0.011 to 0.095)	0.013
2: Individual (n = 96)	−0.064 (−0.096 to −0.032)	<0.001	−0.039 (−0.074 to −0.003)	0.035
Loss of relatives/friends				
Yes = 1, No = 0	0.002 (−0.009 to 0.013)	0.722	−0.005 (−0.018 to 0.008)	0.438
Age				
(continuous)	0.001 (−0.002 to 0.002)	0.939	−0.012 (−0.015 to −0.009)	<0.001
Equivalent income (ref.: <2 million = 0)				
≥2 million = 1	−0.004 (−0.015 to 0.006)	0.402	−0.004 (−0.017 to 0.009)	0.532
Employment status				
1: Employment, 0: Nonemployment	0.016 (0.001 to 0.032)	0.049	−0.016 (−0.037 to 0.005)	0.141
Divorce or bereavement				
1: Yes, 0: No	−0.033 (−0.053 to −0.013)	0.001	−0.003 (−0.030 to 0.024)	0.807
Living alone				
1: Yes, 0: No	0.015 (−0.008 to 0.038)	0.206	0.021 (−0.003 to 0.045)	0.091
Depressive symptoms				
1: Higher risk (≥5), 0: Lower risk (≤4)	−0.033 (−0.044 to −0.022)	<0.001	−0.041 (−0.054 to −0.029)	<0.001

Before the 2011 disaster, Iwanuma city was administratively divided into 99 districts—called gyouseiku—which formed the basis of social organization. For example, residents of individual gyouseiku were encouraged by the city to conduct periodic disaster preparedness drills together and to self-organize local volunteer fire brigades (*23*). After the disaster, the residents who moved together with their neighbors into the temporary shelters continued to organize a variety of communal activities within the trailer home villages—for example, meeting regularly with local officials to improve the delivery of services and connecting residents to nonprofit organizations and local government officials (*23*). Group relocation thereby enabled victims to preserve and even strengthen the social connections predating the disaster throughout the recovery process.

On the other hand, social cohesion was not improved among respondents who experienced group relocation. The living conditions are likely to have deteriorated compared to the pre-disaster situation. For example, the public trailer houses (which resembled shipping container boxes) afforded very little privacy from neighbors (*24*), and many suffered from poor insulation during winter (*2*). The social friction and tension caused by living in close proximity to each other might have deleteriously affected cognitive social capital (Tables 3 and 4) (*25*, *26*).

In contrast to residential relocation, the loss of relatives and/or friends in the disaster was not significantly associated with changes in either dimension of social capital. However, we did not inquire in the baseline survey about the frequency of social interactions between survivors and their relatives and/or friends who lost their lives.

A major strength of this study is the availability of information predating the disaster about social capital and other related variables. Our natural experiment design reduced endogenous selection bias through restriction of the subsample analysis to residents who lived in the same tsunami-inundated area (tables S3 and S4). In addition, the design was able to address the problem of recall bias effectively in most studies conducted in post-disaster settings.

However, the limitation that we were unable to control for unobserved selection factors that determined differences in the type of relocation remains. Selection bias might have occurred because of the 59% response rate to the baseline survey. However, this response rate is quite comparable to similar surveys involving community-dwelling residents (*27*). In addition, we confirmed that the demographic profile of our analytic sample is similar to the rest of Iwanuma residents aged 65 years or older (table S1). Moreover, the response rate of our follow-up survey among survivors was quite high (82.1%). Because of the compulsory residential registration system in Japan, only 17 residents from the baseline sample could not be tracked (Fig. 2). An additional limitation is that we did not measure bridging and linking social capital (*28*) derived from collaborating with nonprofit organizations and the local government of Iwanuma city.

In conclusion, our study suggested that group relocation—resettling the community together—may help preserve social capital, contributing

Table 4. Effects of disaster damage on social capital among respondents who lived in the inundated area (n = 523).

	Outcome: Normalized social cohesion		Outcome: Normalized informal socializing and social participation	
	β Coefficient (95% CI)	*P*	β Coefficient (95% CI)	*P*
Relocation (ref. no.)				
1: Group (n = 78)	−0.022 (−0.069 to 0.025)	0.351	0.076 (0.027 to 0.125)	0.002
2: Individual (n = 42)	−0.063 (−0.112 to −0.013)	0.014	−0.016 (−0.064 to 0.031)	0.503
Loss of relatives/friends				
Yes = 1, No = 0	−0.017 (−0.051 to 0.016)	0.305	−0.027 (−0.063 to 0.009)	0.144
Age				
(continuous)	−0.001 (−0.009 to 0.008)	0.907	−0.015 (−0.023 to −0.006)	0.001
Equivalent income (ref.: < 2 million = 0)				
≥2 million = 1	−0.009 (−0.048 to 0.031)	0.646	−0.006 (−0.047 to 0.035)	0.765
Employment status				
1: Employment, 0: Nonemployment	−0.003 (−0.047 to 0.041)	0.893	−0.021 (−0.062 to 0.020)	0.310
Divorce or bereavement				
1: Yes, 0: No	−0.051 (−0.097 to −0.004)	0.032	−0.019 (−0.076 to 0.039)	0.513
Living alone				
1: Yes, 0: No	0.020 (−0.032 to 0.073)	0.450	0.019 (−0.033 to 0.071)	0.476
Depressive symptoms				
1: Higher risk (≥5), 0: Lower risk (≤4)	−0.015 (−0.050 to 0.020)	0.403	−0.041 (−0.076 to −0.006)	0.022

to improved disaster resilience. At the same time, our study should be viewed as an intermediate stage in a longer-term follow-up study of residential resettlement after disaster. In April 2016, Iwanuma city closed down the trailer park, and all residents were relocated for a second time into permanent housing built by the city. We can anticipate that this second move out of temporary housing and into final or permanent housing will have additional impacts on the social capital of residents.

MATERIALS AND METHODS

Study participants

JAGES is a nationwide cohort study established in 2010 to examine prospectively the predictors of healthy aging. A total of 169,215 community-dwelling people aged 65 years or older in 31 municipalities were mailed a baseline questionnaire, and 112,123 individuals responded to the invitation (response rate 66.3%) (*29*).

One of the field sites of the JAGES cohort is based in the city of Iwanuma (with a total population of 44,187 in 2010) (*19*) in Miyagi Prefecture. We mailed questionnaires to every resident aged 65 years or older in August 2010 (n = 8576), using the official residential register. The survey inquired about personal characteristics and their health status. The response rate was 59.0% (n = 5058), which is comparable to other surveys of community-dwelling residents.

The earthquake and tsunami occurred on 11 March 2011, 7 months after the baseline survey was completed. Iwanuma city is a coastal municipality located approximately 80-km west of the earthquake epicenter, so that it was in the direct line of the tsunami that killed 180 residents, damaged 5542 housing, and inundated 48% of the land area (Fig. 1) (*30*).

Approximately 2.5 years after the disaster (starting on October 2013), we conducted a follow-up survey of all survivors. The survey gathered information about personal experiences of disaster as well as updating their health status and social capital. Informed consent was obtained at the time of survey collection.

The detailed flowchart of the analytic sample is presented in Fig. 2. Of the 4380 eligible participants from the baseline survey, we managed to recontact 3594 individuals (follow-up rate, 82.1%). Our analytic sample was reduced to 3421 due to the exclusion criteria of cognitive disability assessed by a standardized in-home assessment under the national Long-Term Care Insurance scheme at baseline, incompletely signed informed consent, and lack of linkage to the data.

The survey procedures were in accordance with the guidelines on human subject studies and were 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 variables

Our primary outcome of interest was the pre-/post-disaster change in residents' social capital. In our survey, the cognitive component of social

capital was assessed on the basis of responses to questionnaire items about residents' perceptions of trust in the community, levels of mutual help, and community attachment. These 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 (Cronbach's $\alpha = 0.767$).

The structural dimension of social capital was measured by the frequency of meeting with friends, the number of friends whom the respondent met during the past month, and the frequency of those participating in sports and hobby clubs per week. Respondents were asked the following: "How often do you see your friends?" (frequency meeting with friends: 1, rarely; 6, almost everyday); "How many friends/acquaintances have you seen over the past month? Count the same person as one, no matter how many times you have seen him/her." (number of friends who met: 1, none; 5, 10 or more); "How often do you attend activities for sports club? (frequency participating to sports club: 1, none; 6, almost everyday); and "How often do you attend activities for hobby club? (frequency participating to hobby club: 1, none; 6, almost everyday) (Cronbach's $\alpha = 0.705$).

Explanatory variables

We inquired about personal experiences relating to the earthquake and tsunami, including involuntary resettlement due to housing damage as well as loss of relatives and/or friends. Respondents were asked to select from (i) relocated to publicly provided prefabricated temporary housing (kasetsu jutaku, which resembled FEMA-style trailer parks in the United States) together with other community members (group relocation) or (ii) individually relocated to public housing via lottery, moved to rental housing on the open market, or built new homes (individual relocation).

Covariates

We selected as potential time-varying confounding variables: age, household equivalized income, employment status, marital status (married, divorce, or widowed), and living status (living alone or not). In addition, we inquired about depression symptoms (*31*), using the Geriatric Depression Scale–15 (*32*).

Household equivalized income was computed by dividing the gross income by the square root of the number of household members. Then, we constructed a discrete income variable that takes zero if a household's income is "under 2.0 million JPY" and one if income is "2.0 million JPY and over." Depressive symptoms were categorized into lower risk (four points and under) versus higher risk (five points and over) (*32*).

Statistical analysis

We conducted an exploratory factor analysis to confirm the factor structure of our seven items measuring social capital and calculated normalized arithmetic mean by each subscale with higher scores indicating higher levels of social capital (*22*).

An individual fixed-effects regression was adopted to examine the associations between disaster experiences and changes in social capital over time. In the case of two-wave panel data, the model is equivalent to a first-difference model (*33*). That is, the model estimates within-individual changes in the dependent variable (ΔY: change in social capital) are regressed on changes in the independent variable (ΔX: experiences of disaster damage), which effectively differences out the confounding influences of all observed and unobserved time-invariant factors.

We also conducted subsample analyses ($n = 523$) to address endogenous selection bias. Pre-disaster characteristics were systematically correlated with different types of resettlement as well as loss of relatives and/or friends (table S3). Although we controlled for these potential confounding variables in our multivariate fixed-effects models, there is nevertheless a possibility of residual confounding. Therefore, we conducted a subgroup analysis restricted to respondents who lived in the tsunami-inundated area: In this group, the different personal characteristics showed insignificant systematic correlations with disaster experiences (table S4).

To address potential bias due to missing data, we used multiple imputation by the Markov chain Monte Carlo method, assuming missingness at random for explanatory variables and covariates. We created five imputed data sets and combined each result of analysis using the Stata command "mi estimate." All analyses were performed using STATA version 14.0 (STATACorp LP.).

SUPPLEMENTARY MATERIALS

Supplementary material for this article is available at http://advances.sciencemag.org/cgi/content/full/3/7/e1700426/DC1

fig. S1. Timeline of relocation among respondents.

table S1. Comparison of baseline characteristics of all analytic samples, selected samples, and local census population aged 65 years or older in 2010.

table S2. Sex- and age-adjusted averaged social capital scores at both surveys.

table S3. Distribution of disaster experiences among baseline covariates for all analytic samples ($n = 3421$).

table S4. Distribution of disaster experiences among baseline covariates for respondents who lived in the inundated area ($n = 523$).

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