Social capital and cognitive decline in the aftermath of a natural disaster: a natural experiment from the 2011 Great East Japan Earthquake and Tsunami

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Summary

Background No previous studies have examined that social capital mitigates impacts of natural disaster experiences on cognitive function. We aimed to examine prospectively whether social capital mitigates the adverse effects of natural disaster on cognitive decline.

Methods In this natural experiment, the baseline for our study was established 7 months before the 2011 Great East Japan Earthquake and Tsunami in a survey of older community-dwelling adults who lived 80 km west of the epicentre (59·0% response rate). About 2 and a half years after the disaster, which occurred on March 11, 2011, the follow-up survey collected information about personal experiences of disaster as well as incidence of cognitive disability. Our primary outcome was cognitive disability (measured on an 8-level scale) assessed by in-home assessment.

Findings We obtained 5058 respondents at the baseline survey (59·0% response rate) and re-contacted 3594 survivors in the follow-up survey (82·1% follow-up rate). The experience of housing damage was associated with risk of cognitive impairment (coefficient 0·05 [95% CI 0·03 to 0·07]). Factor analysis of our analytical sample (n=3566) established two subscales of social capital: a cognitive dimension (perceptions of community social cohesion) and a structural dimension (informal socialising and social participation). Fixed effects regression indicated that improved informal socialising and social participation mitigated the risk of cognitive decline due to housing damage (coefficient –0·10 [95% CI –0·14 to –0·05]) and deteriorating informal socialising and social participation aggravated the effect of housing damage on cognitive decline (coefficient 0·04 [0·01 to 0·07]).

Interpretation Improved informal socialising and social participation reduces the risk of cognitive decline due to housing damage in the aftermath of natural disasters. Interventions to promote civic participation should be tried to promote cognitive resilience of older survivors.

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Introduction

In the aftermath of the 2011 Great East Japan Earthquake and Tsunami, which occurred on March 11, 2011, 89% of the post-disaster related deaths (3123 seniors of 3523 total deaths reported on Sept 30, 2016) were older residents who were 65 years old or older.[1] A particular concern for older survivors is the potential risk of cognitive decline. We have previously reported that experience of disaster—particularly housing damage—is associated with an increased risk of cognitive decline among older survivors.[2]

In turn, a wealth of epidemiological evidence suggests that the preservation of cognitive function in older individuals is dependent on their ability to maintain social connections in the community.[3] To improve disaster resilience and protect the health of older adults, it is increasingly recognised that preserving social connections in the community—also referred to as social capital—serves as a crucial ingredient.[4,5] According to Aldrich (2012),[6] communities endowed with higher stocks of social capital—ie, 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, no previous study has shown whether social capital mitigates the effect of disaster experiences on cognitive decline.

Social capital is often separated into cognitive and structural components. The former refers to how people perceive social relations in their community (eg, trust of others, mutual help, and community attachment), while the latter component captures what people actually do (eg, informal socialising with their neighbours and participation in social activities).[7]

We aimed to prospectively examine the association between changes in individual social capital and cognitive function, spanning the experience of disaster under a natural experiment.

Research in context

Evidence before this study
We searched PubMED for manuscripts published in any language from database inception to Jan 24, 2017, using the following search terms: [("disaster"[Title/Abstract] OR "earthquake"[Title/Abstract]) AND ("social capital"[Title/Abstract]) AND ("Cognitive Disorders"[MeSH Major Topic]] OR "dementia"[Title/Abstract])]. We specified "MeSH Major Topic" for "cognitive disorders" and searched in title or abstract for rest of words. As a result of the search using these inclusion criteria, we could not identify any articles. That is, to the best of our knowledge, no previous studies have examined whether social capital can buffer the effect of natural disaster experiences on cognitive function.

Added value of this study
Previous studies have shown that disaster experiences are linked to heightened risk of cognitive decline among affected older individuals in the aftermath of the 2011 Great East Japan Earthquake as well as Hurricanes Katrina and Rita. Previous studies also suggested that social capital is protectively associated with depression and post-traumatic stress disorder following disasters. Our study extends the evidence that social capital buffers the effects of disaster experiences on cognitive decline. This study shows that informal socialising and social participation can buffer the adverse effect of housing damage on cognitive function among older survivors of natural disaster.

Implications of all the available evidence
Improved informal socialising and social participation reduces the risk of cognitive decline due to housing damage in the aftermath of natural disasters. Interventions to promote civic participation should be tried to promote cognitive resilience of older survivors.

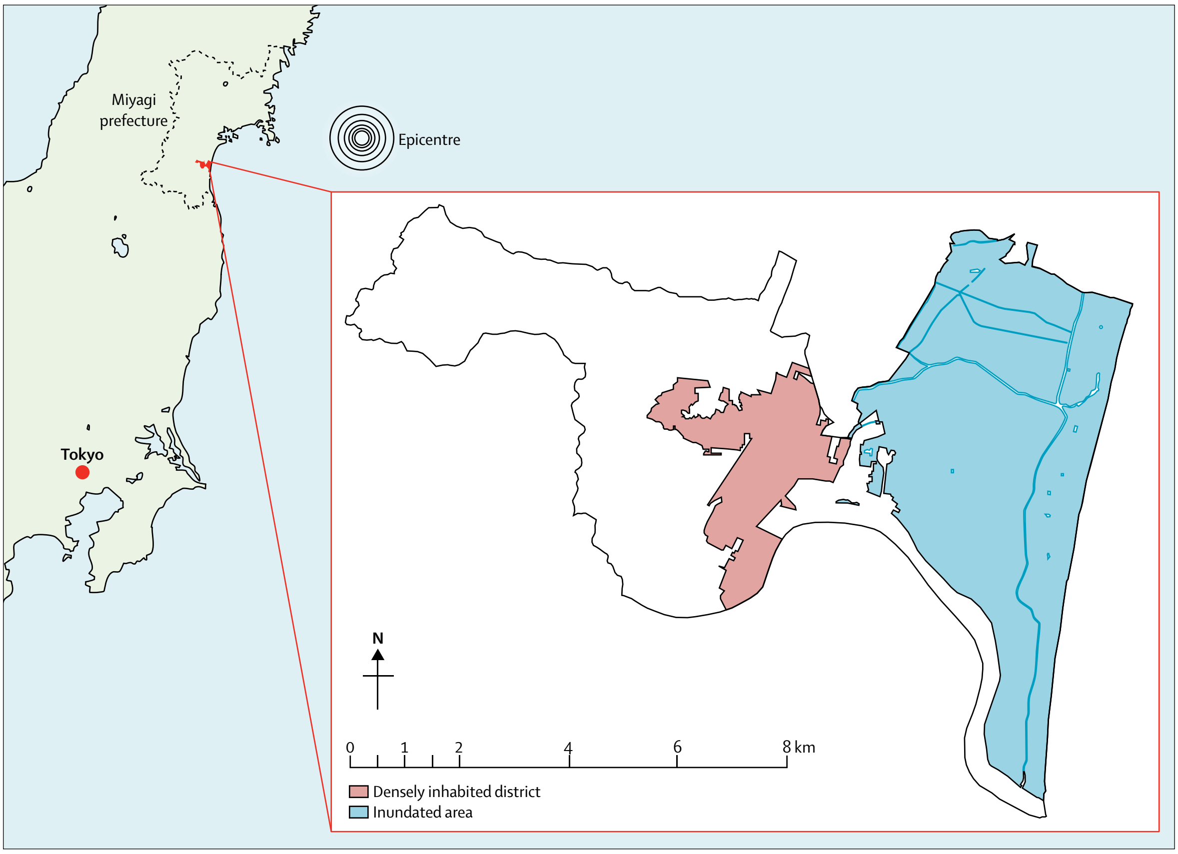

Figure 1: **Map of inundated area in Iwanuma City, Japan**

Methods

Study design and participants

In this study, we took advantage of a unique natural experiment in which information about social capital and cognitive function was collected in August, 2010, 7 months before the 2011 Great East Japan Earthquake and Tsunami, which occurred on March 11. The Japan Gerontological Evaluation Study (JAGES) was established in 2010 as a nationwide sample of community dwelling residents aged 65 years or older. Our study area, Iwanuma city—located about 80 km west of the earthquake epicentre—was one of the field sites of the JAGES cohort. About 2·5 years after the disaster, we re-contacted the 3594 survivors aged 65 and older and linked their responses to incident cognitive disability ascertained by in-home assessment and medical examination under Japan's national Long-Term Care Insurance (LTCI) registry.

One of the field sites of the JAGES cohort is based in the city of Iwanuma (total population 44 187 in 2010) 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 as well as 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 March 11, 2011, 7 months after the baseline survey was completed. Iwanuma city is a coastal municipality located about 80 km west of the earthquake epicentre, so that it was in the direct line of the tsunami that killed 180 residents, damaged 5542 houses, and inundated 48% of the land area (figure 1).[8]

About 2·5 years after the disaster (starting on October, 2013), we did a follow-up survey of all survivors. The survey collected information about personal experiences of disaster as well as updating their health status. The respondents were then linked to the national LTCI registry, which includes information about cognitive impairment based on in-home assessment by trained investigators (eg, public health nurse).

The detailed flow-chart of the analytic sample is presented in figure 2. Of the 4380 eligible participants from the baseline survey, we managed to re-contact 3594 individuals (follow-up rate: 82·1%). Our analytic sample is 3566 due to incompletely signed informed consent forms and absence of linkage to the national LTCI database.

Informed consent was obtained at the time of survey collection. 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.

Outcomes

Our primary outcome was level of cognitive decline assessed by a standardised in-home assessment under a national LTCI scheme established in 2000.[9] An applicant is assessed for eligibility to receive long-term care (eg, meals on wheels) by a trained investigator dispatched from the certification committee in each municipality.

During the home visit, every individual was assessed with regard to their activities of daily living and instrumental activities of daily living status, cognitive function (eg, short-term memory, orientation, and communication) as well as presence of mental and behavioural disorders (eg, delusions of persecution, confabulation, and soliloquy) using a protocol standardised under the long-term care insurance scheme.

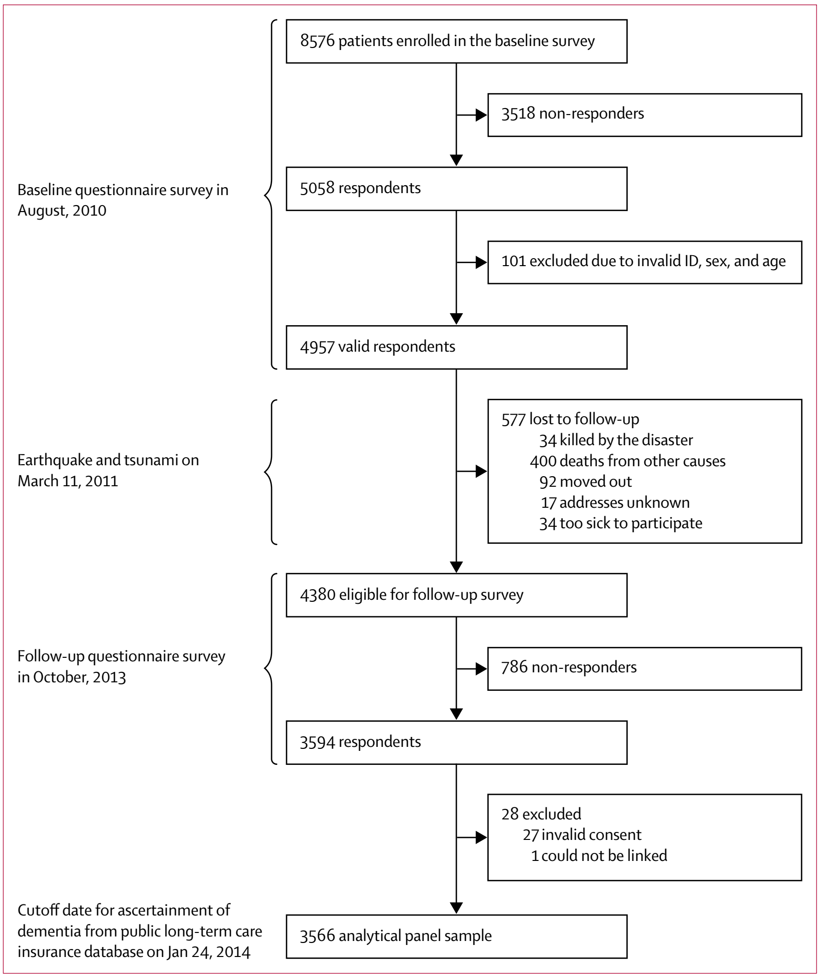

Figure 2: **Flow chart for the analytical panel sample (n=3566) aged 65 years and older, Iwanuma, Japan, 2010–13**
ID=identification number.

Following the assessment, the applicants are classified into one of 8 levels (1=independent to 8=requires specialised medical treatment) according to the severity of their cognitive disability (appendix p 2).[2] This index of cognitive impairment is strongly associated with the Mini Mental State Examination (Spearman's rank correlation ρ=–0·73, p<0·001)[10] and level 1 of the 8-point scale has been shown to correspond with a 0·5 point rating on the Clinical Dementia Rating scale (specificity and sensitivity, 0·88).[11]

See Online for appendix

The initial certification is valid for 6 months, after which periodic re-assessments are done every 12 months. Individuals and their caregivers can request a re-assessment before the expiration date, if their health status changes substantially.[9]

The committee also asks a panel of physicians to independently assess the cognitive disability level of applicants to determine the care requirements of the applicants.[12] The medical assessment is done independently of the in-home assessment, but we confirmed a high association between these two methods of

	Baseline survey in August, 2010		Follow-up survey in October, 2013	
	n (%)	Mean (SD)	n (%)	Mean (SD)
Cognitive impairment level				
Independent	3421 (96%)	..	3156 (89%)	..
I	77 (2%)	..	181 (5%)	..
IIa	6 (<1%)	..	51 (1%)	..
IIb	52 (2%)	..	116 (3%)	..
IIIa	8 (<1%)	..	43 (1%)	..
IIIb	2 (<1%)	..	15 (<1%)	..
IV	0	..	4 (<1%)	..
M	0	..	0	..
Missing	0	..	0	..
Housing damage*				
No damage	..	..	1423 (40%)	..
Affected	..	..	1496 (42%)	..
Minor	..	..	257 (7%)	..
Major	..	..	131 (4%)	..
Destroyed	..	..	158 (4%)	..
Missing	..	..	101 (3%)	..
Loss of relatives and friends*				
No	..	..	2166 (61%)	..
Yes	..	..	1329 (37%)	..
Missing	..	..	71 (2%)	..
Age				
Continuous†	3566 (100%)	73·64 (6·28)	3566 (100%)	76·84 (6·29)
Missing	0	..	0	..
Equivalised income				
Less than 2·0 million JPY	1422 (40%)	..	1586 (45%)	..
2·0 million JPY and more	1489 (42%)	..	1400 (39%)	..
Missing	655 (18%)	..	580 (16%)	..
Stroke				
No	2664 (75%)	..	2845 (80%)	..
Yes	77 (2%)	..	196 (5%)	..
Missing	825 (23%)	..	525 (15%)	..
Diabetes				
No	2285 (64%)	..	2551 (71%)	..
Yes	456 (13%)	..	490 (14%)	..
Missing	825 (23%)	..	525 (15%)	..
Depressive symptoms (GDS-15)				
4 points and less	2090 (58%)	..	2072 (58%)	..
5 points and higher	984 (28%)	..	1026 (29%)	..
Missing	492 (14%)	..	468 (13%)	..
Current drinking				
No	2208 (62%)	..	2421 (68%)	..
Yes	1277 (36%)	..	1121 (31%)	..
Missing	81 (2%)	..	24 (1%)	..
Current smoking				
No	2903 (82%)	..	3265 (91%)	..
Yes	366 (10%)	..	278 (8%)	..
Missing	297 (8%)	..	23 (1%)	..

(Table 1 continues on next page)

assessment (Pearson's correlation γ= 0·80, p=0·0001). In our primary analyses, we used the in-home assessment as our outcome, but in sensitivity analyses we also used the medical examination data.

We linked JAGES cohort participants to the LTCI register in Iwanuma city for the follow-up period from April 1, 2010, to Jan 24, 2014.

Explanatory variables

Our primary exposure variables are the cognitive and structural dimensions of social capital. The cognitive dimension was assessed based on answers to questionnaire items about residents' perceptions of trust of others 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".

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 participating in sports and hobby clubs per week. Respondents were asked "How often do you see your friends?" (1=rarely, 6=almost every day); "How many friends/acquaintances have you seen over the past month?" (1=none, 5=10 or more); "How often do you attend sports or hobby group activities?" (1=not at all, 6=almost every day).

We also inquired about personal experiences of damage in the earthquake and tsunami—ie, damage or loss of housing as well as loss of relatives or friends. Two or more technical officers surveyed property damage and the local government certificated the result (appendix p 3).

Covariates and risk factors

We selected as time-varying confounding variables: age, equivalised income, medical diagnosis of stroke and diabetes,[13] depression symptoms (measured by the Geriatric Depression Scale-15 [GDS-15]),[14] smoking, drinking,[15] and daily walking time.[16] Other time invariant characteristics, such as sex and educational attainment, were omitted from our fixed effects regressions.[17] We also controlled for length of time (in years) between the pre-disaster and post-disaster assessments for each subject (mean 3·69 [SD 0·38]).[2]

Household income was equalised by dividing the gross income by the square root of the number of household members and categorised into "Less than 2·0 million JPY" versus "2·0 million JPY and higher". Depressive symptoms were categorised into lower risk (4 points and lower) versus higher risk (5 points and higher).[18]

Statistical analysis

We used a fixed effects (or first difference) model in which we regressed within-individual changes in the dependent variable (Y: change in level of cognitive impairment) on changes in the independent variable (X: change in level of social capital), which differences out the confounding influences of all observed and unobserved time-invariant factors.

We did an exploratory factor analysis with principal factor method followed by promax rotation to confirm the factor structure of our seven items measuring social capital and examined the effect of each sub-scale of social capital on cognitive decline.

We hypothesised that improvements in social capital (before *vs* after the disaster) will buffer the effect of disaster experiences on cognitive decline, while declines in social capital will have the opposite effect. To understand these interactions, we stratified the baseline sample into two groups—"high" social capital before the disaster versus "low" social capital, based on a median split. This resulted in two sets of groups for comparison: (1) people who reported low social capital both before and after the disaster (reference group) versus people who experienced improvements in social capital after the disaster ("2010 low and 2013 high"); and (2) people who reported high social capital both before and after the disaster (reference) versus people who experienced declining social capital after the disaster ("2010 high and 2013 low").

To address potential bias due to missing data, we used multiple imputation by 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".

Data were analysed with STATA version 14.0 (STATA Corp LP, College Station, TX, USA).

Role of the funding source

The funders had no role in the design or conduct of the study; nor collection, management, analysis, and interpretation of the data; nor preparation, review, or approval of the manuscript; nor the decision to submit the manuscript for publication. The corresponding author had full access to all the data in the study and assumes final responsibility for the decision to submit for publication.

	Baseline survey in August, 2010		Follow-up survey in October, 2013	
	n (%)	Mean (SD)	N (%)	Mean (SD)
(Continued from previous page)				
Walking time per day				
Less than 30 min	1284 (36%)	..	1281 (36%)	..
30–59 min	1183 (33%)	..	1227 (34%)	..
60–89 min	493 (14%)	..	534 (15%)	..
90 min and more	435 (12%)	..	470 (13%)	..
Missing	171 (5%)	..	54 (2%)	..
Perceived mutual help between neighbours†				
1: Not at all–5: Very much	3456 (97%)	3·54 (0·83)	3483 (98%)	3·53 (0·80)
Missing	110 (3%)	..	83 (2%)	..
Trust of neighbours†				
1: Not at all–5: Very much	3487 (98%)	3·75 (0·77)	3511 (99%)	3·74 (0·72)
Missing	79 (2%)	..	55 (2%)	..
Community attachment†				
1: Not at all–5: Very much	3484 (98%)	4·00 (0·83)	3517 (98%)	3·95 (0·82)
Missing	82 (2%)	..	49 (1%)	..
Frequency meeting with friends†				
1: Rarely–6: Almost everyday	3414 (96%)	3·73 (1·48)	3517 (99%)	3·63 (1·57)
Missing	152 (4%)	..	49 (1%)	..
Number of friends who met for the past month†				
1: None–5: 10 or more	3387 (95%)	3·58 (1·27)	3507 (98%)	3·42 (1·35)
Missing	179 (5%)	..	59 (2%)	..
Frequency participating to sports club†				
1: None–6: Almost everyday	2991 (84%)	1·86 (1·43)	3421 (96%)	1·78 (1·42)
Missing	575 (16%)	..	145 (4%)	..
Frequency participating to hobby club†				
1: None–6: Almost everyday	3048 (85%)	2·25 (1·46)	3428 (96%)	1·90 (1·38)
Missing	518 (15%)	..	138 (4%)	..
Sex (time-invariant variable)‡				
Male	1552 (44%)	..	..	..
Female	2014 (56%)	..	..	..
Missing	0	..	..	..
Educational attainment (time-invariant variable)‡				
9 years and less	1229 (34%)	..	..	..
10 years and more	2199 (62%)	..	..	..
Missing	138 (4%)	..	..	..

Data are n (%) showing the number of responses and number missing, totalling n=3566 and mean (SD) showing averaged scores among the respondents. JPY=Japanese Yen. GDS-15=Geriatric Depression Scale-15. *Empty cells at baseline due to before the disaster. †Empty cells at follow-up due to time-invariant variables. ‡Continuous variables.

Table 1: **Characteristics of overall analytical sample at baseline and follow-up survey (n=3566) aged 65 years and older, Iwanuma, Japan, 2010–13**

Results

We obtained 5058 respondents at the baseline survey (59·0% response rate) and re-contacted 3594 survivors in the follow-up survey (82·1% follow-up rate). Table 1 presents the characteristics of respondents at baseline (before the disaster) and at follow-up 2·5 years after the disaster. From the comparison with results of the local census at baseline (appendix p 4), women made up 57% (n=2014) of respondents, and this proportion is very close to the actual census of older residents in Iwanuma city in October, 2010 (men 43% [n=3735], women 57% [n=4988]).[19] The age distribution of our sample is also close to the local census data except for the group aged 85 years and older (respondents 6% [n=220], census data 13% [n=1150]).[19] A somewhat higher proportion of our respondents were married (n=2460 [71%]) compared with the census data (n=5618 [65%]).[20] The proportion of employed individuals in our data (n=560 [18%]) was also quite close to the census data (n=1493) [17%]).[21] These

	Model 1: Main effects		Model 2: Added interaction terms of housing damage and social capital	
	Coefficient (95% CI)	p value	Coefficient (95% CI)	p value
Housing damage				
1: None–5: Destroy (continuous)	0·05 (0·03 to 0·07)	<0·0001	0·04 (0·02 to 0·06)	0·0002
Loss of relatives or friends				
Yes=1, No=0	−0·03 (−0·08 to 0·02)	0·021	−0·02 (−0·07 to 0·02)	0·32
Age				
(Continuous)	0·32 (0·27 to 0·36)	<0·0001	0·30 (0·26 to 0·35)	<0·0001
Equivalent income				
≥2 million JPY=1, <2 million JPY=0	−0·01 (−0·06 to 0·04)	0·78	−0·01 (−0·05 to 0·04)	1·00
Stroke				
Yes=1, No=0	0·23 (0·11 to 0·34)	0·0001	0·20 (0·10 to 0·31)	0·0003
Diabetes				
Yes=1, No=0	−0·01 (−0·11 to 0·09)	0·87	−0·01 (−0·11 to 0·09)	0·87
Depressive symptoms				
≥5=1, ≤4=0	0·10 (0·04 to 0·15)	0·0011	0·09 (0·04 to 0·15)	0·0014
Current drinking				
Yes=1, No=0	0·05 (−0·03 to 0·13)	0·20	0·04 (−0·04 to 0·12)	0·30
Current smoking				
Yes=1, No=0	−0·07 (−0·18 to 0·05)	0·24	−0·06 (−0·18 to 0·05)	0·28
Increased walking time				
1: <30 min–4: ≥90 min (continuous)	−0·04 (−0·06 to −0·02)	0·0009	−0·04 (0·06 to −0·01)	0·0013
Length of time between pre-disaster and post-disaster assessment				
Continuous	−0·25 (−0·28 to −0·21)	<0·0001	−0·24 (−0·27 to −0·20)	<0·0001
Social cohesion				
Continuous	−0·04 (−0·08 to −0·01)	0·0314	−0·04 (−0·07 to −0·01)	0·0378
Informal socialising and social participation				
Continuous	−0·06 (−0·10 to −0·03)	0·0001	−0·06 (−0·09 to −0·03)	0·0001
Interaction term: housing damage × social cohesion				
Continuous	··	··	−0·01 (−0·03 to 0·02)	0·78
Interaction term: housing damage × informal socialising and social participation				
Continuous	··	··	−0·07 (−0·08 to −0·05)	<0·0001

JPY=Japanese Yen.

Table 2: **Effects of disaster experiences and social capital on changes in cognitive impairment level in overall analytical sample (n=3566) aged 65 years and older, Iwanuma, Japan, 2010–13**

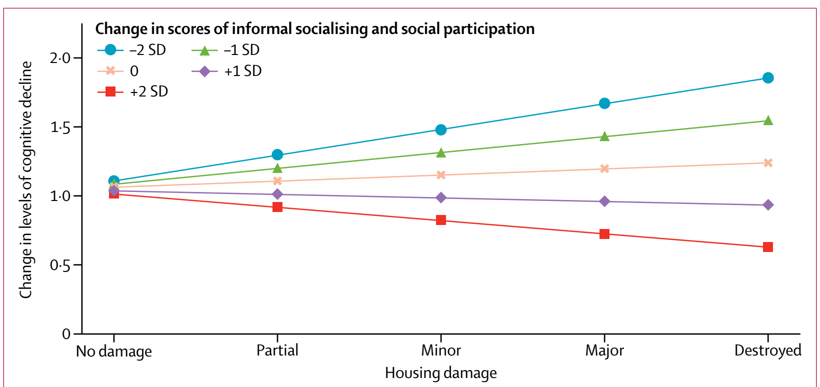

Figure 3: **Marginal effect of the interaction of housing damage × informal socialising or social participation in the overall analytical sample (n=3566) aged 65 years and older, Iwanuma, Japan, 2010–13**

comparisons support the representativeness of our data relative to Iwanuma city as a whole.

In addition, we also compared the characteristics of our analytic sample to non-respondents at the follow-up survey (n=786). The sex distribution was similar, although our analytic sample was somewhat older than the non-respondents (appendix p 4). The proportion of married people in our analytical sample (n=2460 [71%]) was higher than among non-respondents (n=469 [65%]). More respondents were likely to be employed at the time of the follow-up survey (n=560 [18%]) compared with the non-respondents (n=93 [14%]). The non-respondents were also less likely to be classified as functionally independent (n=659 [84%]) compared with the analytical sample (n=3421 [96%]). This could have resulted in some attrition bias, but the differences were not large (appendix p 4).

Among the respondents, 1329 (37%) reported losing relatives or friends in the disaster, while 2042 (57%) reported personal damage to their property (table 1). The prevalence of respondents whose cognitive function was classified as non-independent at the follow-up survey (n=410 [11%]) was three times higher than at baseline (n=145 [4%]). The prevalence of stroke (n=75 [2%]) had also increased (n=196 [5%]) at the follow-up survey. In addition, all components of social cohesion and informal socialising and social participation decreased during the follow-up.

The results of the factor analysis supported our approach to create two subscales for social capital—one representing the cognitive dimension (social cohesion) and the other representing the structural dimension (informal socialising and social participation; appendix p 5). Each eigenvalue of the subscales exceeded 1·0 (1·80, 1·14, respectively) thereby fulfilling the Kaiser-Guttman criterion,[22] and they explained 73% and 46% of the total variance, respectively. The subscales had good internal consistency reliability, with Cronbach's α=0·77 and 0·71, respectively (appendix p 5).

We calculated sex-adjusted and age-adjusted averaged cognitive disability scores at both surveys according to the four patterns of transition in social capital before versus after the disaster (appendix p 6). Respondents who reported declining levels of social capital (2010 high to 2013 low) showed an increase in the level of cognitive impairment at the follow-up survey (1·11 to 1·38, for social cohesion; 1·06 to 1·28, for informal socialising and social participation).

As shown in model 1 of table 2, the fixed effects model for the overall samples indicated that housing damage was associated with higher risk of cognitive impairment (coefficient=0·05 [95% CI 0·03 to 0·07]), while the main effects for social cohesion and informal socialising and social participation were protectively associated with cognitive impairment (coefficient=−0·04 [95% CI −0·08 to −0·01]; and coefficient −0·06 [95% CI −0·10 to −0·03], respectively). In addition, the interaction term for housing damage × informal socialising and social participation was also significant (p<0·0001; figure 3). Sensitivity analyses using the results of medical examination also showed similar results (appendix p 7).

In the subgroup analysis comparing 2010 low and 2013 low versus 2010 low and 2013 high, the interaction term for housing damage × informal socialising and social participation was also significant (p<0·0001; model 2 in table 3). In the comparison of 2010 high and 2013 high versus 2010 high and 2013 low, the interaction term of housing damage × informal socialising and social participation was also significant (p=0·0131; model 2 in table 4). That is, informal socialising and social participation seemed to buffer the effect of housing damage on cognitive impairment.

Although the interaction terms for housing damage × social cohesion was not significant in any of the models, the point estimates were in the expected direction (tables 2–4; appendix pp 7–9).

We also added an analysis for incident cognitive disability between 2010 (pre-disaster) and 2013 (post-disaster). Our outcome variable is now a binary (0,1) variable indicating whether someone changed from being classified as "independent" to a score of "1 or above" on the 8-level cognitive impairment scale. The interaction term of housing damage × informal socialising and social participation was marginally significant (appendix p 10).

	Model 1: social cohesion (n=1487)		Model 2: Informal socialising and social participation (n=1818)	
	Coefficient (95% CI)	p value	Coefficient (95% CI)	p value
Housing damage				
1: None–5: Destroy (continuous)	0·04 (0·01 to 0·07)	0·0313	0·07 (0·03 to 0·10)	0·0003
Loss of relatives or friends				
Yes=1, No=0	–0·04 (–0·12 to 0·03)	0·21	–0·04 (–0·12 to 0·05)	0·37
Age				
Continuous	0·33 (0·27 to 0·39)	<0·0001	0·36 (0·28 to 0·43)	<0·0001
Equivalent income				
≥2 million JPY=1, <2 million JPY=0	0·01 (–0·08 to 0·08)	0·92	0·01 (–0·07 to 0·09)	0·87
Stroke				
Yes=1, No=0	0·29 (0·12 to 0·45)	0·0005	0·24 (0·04 to 0·44)	0·0216
Diabetes				
Yes=1, No=0	–0·03 (–0·17 to 0·12)	0·71	0·08 (–0·12 to 0·28)	0·41
Depressive symptoms				
≥5=1, ≤4=0	0·15 (0·07 to 0·22)	0·0001	0·09 (–0·03 to 0·21)	0·14
Current drinking				
Yes=1, No=0	0·03 (–0·08 to 0·14)	0·55	0·03 (–0·11 to 0·18)	0·64
Current smoking				
Yes=1, No=0	–0·07 (–0·24 to 0·10)	0·41	–0·11 (–0·31 to 0·09)	0·30
Increased walking time				
1: <30 min–4: ≥90 min (continuous)	–0·02 (–0·05 to 0·02)	0·30	–0·05 (–0·09 to –0·01)	0·0186
Length of time between pre-disaster and post-disaster assessment				
Continuous	–0·25 (–0·31 to –0·20)	<0·0001	–0·27 (–0·34 to –0·21)	<0·0001
Social cohesion				
Continuous	0·03 (–0·03 to 0·08)	0·32	..	..
Interaction term: housing damage × social cohesion				
Continuous	–0·02 (–0·06 to 0·02)	0·43	..	..
Informal socialising and social participation				
Continuous	..	..	–0·04 (–0·10 to 0·02)	0·23
Interaction term: housing damage × informal socialising and social participation				
Continuous	..	..	–0·10 (–0·14 to –0·05)	<0·0001

JPY=Japanese Yen.

Table 3: **Effects of disaster damage and social capital on changes in cognitive impairment level, comparing low-low versus low-high of social capital for stratified sample, aged 65 years and older, Iwanuma, Japan, 2010–13**

Discussion

This study shows that experiences of disaster (particularly, housing damage) are associated with the increased risk of cognitive impairment, while social capital seemed to buffer that association. Subgroup analyses suggested that increased informal socialising and social participation mitigates the effect of housing damage on deterioration of cognitive function, while decreased informal socialising and social participation potentiated the effect of property damage on incident cognitive disability.

The association between changes in social capital and cognitive decline is both statistically and clinically important. For example, the risk of cognitive decline is increased with the level of housing damage (coefficient 0·05 [95% CI 0·03 to 0·07; model 1 in table 2]), meanwhile the risk due to housing damage is reduced by improved informal socialising and social participation (coefficient –0·10 [95% CI –0·14 to –0·05; model 2 in table 3]).

Previous studies have showed that disaster experiences are linked with heightened risk of cognitive decline among affected older individuals in the aftermath of the 2011 Great East Japan Earthquake[2] as well as Hurricanes Katrina and Rita.[23] Studies have also suggested that social capital is protectively associated with depression and post-traumatic stress disorder following disasters.[4] Our study extends the evidence by showing that social capital can buffer the effect of disaster experiences on cognitive decline.

According to Aldrich (2012),[6] the three broad mechanisms by which social capital assists in disaster resilience include: (1) norms of reciprocity serve as a kind of "informal insurance", enabling residents to draw on each other for instrumental and emotional assistance; (2) stronger community bonds enable residents to more effectively "voice" their needs and demands during disaster recovery; and (3) social solidarity raises the cost of "exit" from the community in the aftermath of disaster, thereby enabling the speedier reconstruction of stricken communities. To these we might add yet a fourth mechanism to explain our findings—ie, stronger connections to the community helped older victims from becoming socially isolated after they experienced housing

	Model 1: Social cohesion (n=1404)		Model 2: Informal socialising and social participation (n=1233)	
	Coefficient (95% CI)	p value	Coefficient (95% CI)	p value
Housing damage				
1: None–5: Destroy (continuous)	0·05 (0·02 to 0·08)	0·0022	0·04 (0·01 to 0·06)	0·009
Loss of relatives/friends				
Yes=1, No=0	–0·02 (–0·08 to 0·04)	0·48	–0·01 (–0·06 to 0·05)	0·76
Age				
(Continuous)	0·30 (0·24 to 0·36)	<0·0001	0·24 (0·18 to 0·29)	<0·0001
Equivalent income				
≥2 million JPY=1, <2 million JPY=0	–0·02 (–0·08 to 0·04)	0·56	–0·01 (–0·05 to 0·04)	0·80
Stroke				
Yes=1, No= 0	0·18 (0·02 to 0·33)	0·0221	0·16 (–0·02 to 0·35)	0·08
Diabetes				
Yes=1, No=0	0·02 (–0·12 to 0·15)	0·81	–0·09 (–0·21 to 0·04)	0·16
Depressive symptoms				
≥5 p=1, ≤4=0	0·08 (–0·01 to 0·15)	0·05	0·10 (0·02 to 0·19)	0·0224
Current drinking				
Yes=1, No=0	0·07 (–0·04 to 0·18)	0·24	0·05 (–0·04 to 0·13)	0·31
Current smoking				
Yes=1, No=0	–0·08 (–0·23 to 0·07)	0·32	–0·02 (–0·15 to 0·11)	0·76
Increased walking time				
1: <30 min–4: ≥90 min (continuous)	–0·06 (–0·09 to –0·03)	0·0003	–0·03 (–0·06 to –0·01)	0·0250
Length of time between pre-disaster and post-disaster assessment				
(Continuous)	–0·24 (–0·30 to –0·19)	<0·0001	–0·19 (–0·24 to –0·15)	<0·0001
Social cohesion				
(Continuous)	0·13 (0·07 to 0·19)	0·0001	··	··
Interaction term: housing damage × social cohesion				
(Continuous)	0·03 (–0·01 to 0·08)	0·17	··	··
Informal socialising and social participation				
(Continuous)	··	··	0·10 (0·06 to 0·14)	<0·0001
Interaction term: housing damage × informal socialising and social participation				
(Continuous)	··	··	0·04 (0·01 to 0·07)	0·0131

JPY=Japanese Yen.

Table 4: **Effects of disaster damage and social capital on changes in cognitive impairment level, comparing high-high versus high-low of social capital in stratified sample aged 65 years and older, Iwanuma, Japan, 2010–13**

damage and were relocated to temporary trailer housing. After the disaster, the residents who moved together with their neighbours into the temporary shelters continued to organise a variety of communal activities within the trailer home villages.[24] We hypothesise that these communal activities preserved the social connections between displaced residents, and that mutual support (as well as apparently mundane daily activities such as visiting with neighbors) helped to maintain cognitive functioning among vulnerable seniors.

A major strength of this study is the availability of information predating the disaster about levels of cognitive disability as well as other health conditions. Our design was therefore able to effectively address the problem of recall bias in most studies done in post-disaster settings. A second strength is the record linkage to medically verified cognitive disability obtained during home visits.

An important limitation of our study is that our first differences analyses cannot rule out simultaneity—eg, changes in informal socialising and social participation occurred because of (or at the same time as) changes in cognitive impairment. In the more severe cases of cognitive decline, there is also the possibility of information bias—ie, people did not accurately recall their most recent patterns of socialising with others. On the other hand, the baseline reports of social cohesion and social participation were obtained previous to the disaster, thereby eliminating the possibility of recall bias due to the traumatic events of the disaster itself. Last, selection bias might have arisen due to the somewhat increased proportion of non-respondents in the follow-up survey who were cognitively impaired at baseline. However, our response rate is quite comparable to similar surveys involving community dwelling residents.[25] In addition, we confirmed that the demographic profile of our participants is quite similar to the Census of Iwanuma residents aged 65 years or older (appendix p 4). Furthermore, the response rate of our follow-up survey among survivors was quite high (82%). Owing to the compulsory residential registration system in Japan, only 17 residents from the baseline sample could not be tracked (figure 2).

In conclusion, our findings suggest that social capital mitigates the effect of housing damage on cognitive decline in the aftermath of a natural disaster. A previous mixed methods study questioned 281 survivors of the 2011 Earthquake and Tsunami who had been resettled into trailer homes in the aftermath of the disaster.[26] Compared with those who moved together with other members of their community, survivors who were resettled by lottery (individual relocation) were less likely to report that they received social support from their new neighbours, and also less likely to report that they provided social support to others. Hence the method of relocating disaster victims is likely to have an important effect on their ability to maintain community ties. In addition, interventions that promote civic participation might be effective in promoting cognitive resilience in the aftermath of disasters. The World Bank recently reported on such a campaign in Ofunato, a city in Iwate prefecture that was devastated by the 2011 disaster, called the Ibasho Café initiative (ibasho in Japanese means a place to gather). The project objective was to help to strengthen the social capital needed to recover from the disaster, giving community members of all ages a place where they can develop more and deeper connections with each other.[27]

Contributors

HH, TT, JA, YM, KK, and IK conceived and designed the survey. HH, TT, JA, YM, and KK did the survey. HH analysed the data. HH wrote the first draft of the report. HH, TT, JA, YM, KK, SVS, and IK contributed to the writing of the report. All authors agreed with report results and conclusions.

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Declaration of interests

We declare no competing interests.

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