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Depressive symptoms in the aftermath of major disaster: Empirical test of the social support deterioration model using natural experiment



Koichiro Shiba^{a,*}, Aki Yazawa^a, Shiho Kino^{a,b}, Katsunori Kondo^{c,d}, Jun Aida^e, Ichiro Kawachi^a

^a Department of Social and Behavioral Sciences, Harvard T.H. Chan School of Public Health, 677 Huntington Avenue, Boston, MA 02115, USA

^b Department of Health Education and Health Sociology, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan

^c Center for Preventive Medical Sciences, Chiba University, 1-8-1, Inohana, Chuo-ku, Chiba 260-8670, Japan

^d Center for Gerontology and Social Science, National Center for Geriatrics and Gerontology, 7-430 Morioka-cho, Obu City, Aichi 474-8511, Japan

e Department of International and Community Oral Health, Tohoku University Graduate School of Dentistry, 4-1 Seiryo-machi, Aoba-ku, Sendai, Miyagi 980-8575,

Japan

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ABSTRACT

Introduction: We examined the extent to which the post-disaster deterioration of social support and social capital mediates the associations between disaster-related experiences and depressive symptoms among survivors to test the social support deterioration model.

Methods: We used unique natural experiment data (n = 3567) stemming from the 2011 Great East Japan Earthquake. The follow-up survey was conducted 2.5 years after the disaster. We examined associations between changes in depressive symptoms, disaster-related experiences (loss of loved ones, changes in household income, loss of job, drop in subjective economic status, and home loss), and post-disaster deterioration of four different types of social support (i.e., kin emotional, kin instrumental, non-kin emotional, and non-kin instrumental support), as well as two dimensions of individual-level social capital (i.e., informal socializing and social cohesion). We then performed causal mediation analysis.

Results: We found that there was deterioration of social support and social capital among individuals with disasterrelated experiences. We also found associations between deterioration of social support/capital and worsening of depressive symptoms for specific categories of disaster experiences (i.e., drop in subjective economic status, loss of job, and home loss). However, causal mediation analysis showed little evidence of mediation by post-disaster deterioration of social support/capital. There was some evidence to suggest exposure-mediator interaction such that the association between social support/capital deterioration and depressive symptoms was weaker among those with disaster experiences.

Discussion: The social support deterioration model was not empirically supported among older-adult disaster survivors of the 2011 Great East Japan Earthquake, after accounting for exposure-mediator interactions.

1. Introduction

A common misconception about disasters is that stricken communities are too shocked and helpless to help themselves (Noji, 2000). In contrast to that view, communities have been repeatedly observed to mobilize in the wake of large scale disasters, as witnessed by the armada of volunteers equipped with boats, canoes, and even jet-skis, who converged on Houston to rescue flood victims after Hurricane Harvey (Andone, 2017). Indeed, help from family and community members is often the only form of assistance that disaster victims can rely upon before official emergency response begins to be mobilized.

Numerous studies have emphasized the capacity for local forms of social support – i.e. assistance from kin, friends, and neighbors – to buffer the traumatic effects of disaster (Aldrich, 2012; Tierney, 2019). According to this view, the greater the availability of social support, the more resilient are victims to the mental and physical health consequences of disaster-related damage.

Nevertheless, some disasters are so extensive in scale that after the initial rush to help victims, the level of need exceeds the community's capacity to respond, resulting in the depletion of supportive resources over the longer term. That is, following a "honeymoon" phase of spontaneous assistance, the community's resources for providing social support become eventually exhausted (Kaniasty and Norris, 1993). The reasons for this include that the individuals providing support to others may themselves be affected by the disaster and thus unable to fulfill their obligations. Moreover, local therapeutic communities may be disrupted by

* Corresponding author.

E-mail address: shiba_k@g.harvard.edu (K. Shiba).

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Received 20 April 2020; Received in revised form 2 September 2020; Accepted 29 October 2020 Available online 4 November 2020 2666-5581/© 2020 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/) widespread destruction of housing and residential relocation, followed by a decline in the level of routine daily activities (such as visiting with neighbors) as well as decreased social participation ("putting social life on hold") (Kaniasty and Norris, 2004).

The social support deterioration model developed by Kaniasty and Norris (2009) posits that the depletion of supportive resources contributes to the adversity experienced by disaster survivors (Kaniasty and Norris, 2009). That is, the deterioration of social support (following an initial period of mobilization) is hypothesized to act as an independent risk factor for health outcomes such as mental illness, over and above any direct effects of traumatic experiences. The model stands in stark contrast with the stress buffering model which treats the availability of social support as a protective factor for disaster-affected individuals.

However, empirically testing the support deterioration model has proved to be methodologically challenging because it requires the information about the availability of social support pre-dating the disaster. Asking survivors to retrospectively report their pre-disaster levels of social support is apt to be biased and unreliable. In a small study of older adults (n = 222) who were interviewed three months before and 2- and 4-years after a severe flood in Kaniasty and Norris (1993) found empirical support for the social support deterioration model (Kaniasty and Norris, 1993). Using depressive symptoms (assessed by Center for Epidemiologic Studies Depression Scale) as the outcome, the study found that the decline in social support from non-kin members (friends and neighbors) accounted for the impact of personal loss (physical harm, financial loss, property damage) on depression 3 to 6 months postflood. Moreover, this mediation by non-kin support was complete, leaving personal loss with no direct effect on depression. By contrast, no mediating effect was found for social support from kin members (family and relatives), which the researchers ascribed to the observation that the closer the relationship between the recipient and the potential donor, the stronger the recipient's expectations that help should be offered when needed (Kaniasty and Norris, 1993). The social support deterioration model has been subsequently corroborated in a study of victims from Hurricanes Hugo and Andrew, and broadened to other situations such as exposure to war combat, child abuse, and crime victimization, in which declines in social support were found to mediate the link between trauma exposure and subsequent mental illness (Norris and Kaniasty, 1996; Taft et al., 1999; Vranceanu et al., 2007; Yap and Devilly, 2004).

In the present study, we provide an empirical test of the social support deterioration model based on a unique natural experiment stemming from the 2011 Great East Japan Earthquake in which rich baseline data was obtained before the disaster, enabling us to take account of predisaster differences between groups of survivors as well as post-disaster changes in social support.

2. Methods

2.1. Study population

The Iwanuma Study is part of a nationwide cohort study in Japan, called the Japan Gerontological Evaluation Study (JAGES), which was established in 2010 to examine prospectively the social determinants of healthy aging among older community-dwelling residents (112,123 participants in 31 municipalities; baseline response rate = 66.3%) (Kondo, 2016; Kondo et al., 2018). Iwanuma city was one of the field sites of the JAGES located in Miyagi Prefecture (population 44,187 in 2010), located approximately 80 km (128 miles) from the epicenter of the 2011 Great East Japan Earthquake (Iwanuma City, 2020). The baseline survey of the Iwanuma Study was conducted in August 2010 (i.e., seven months before the disaster), when a census was undertaken of all residents aged 65 years or older in Iwanuma city using the official residential register (n = 8576). A total of 5058 residents responded to the baseline survey (response rate = 59.0%).

The Great East Japan Earthquake (Richter scale: 9.0) occurred on March 11th, 2011. The subsequent tsunami caused devastating damage to coastal areas of northeastern Japan. In Iwanuma city, 189 residents lost their lives, 5542 houses were damaged, and 48% of the land area was inundated (Fig. 1) (Miyagi Prefecture, 2016). The follow-up survey targeting the survivors from the baseline survey was conducted approximately 2.5 years after the disaster (2013). Of the eligible survivors who were healthy enough to participate and still lived in Iwanuma at the time of follow-up, 3594 responded to our mailed follow-up survey, yielding a follow-up rate of 82.1%. Our analytic sample was 3567 subjects after excluding invalid responses (Fig. 2).

2.2. Measurements

2.2.1. Outcome

Depressive symptoms were measured using the Japanese shortversion of Geriatric Depression Scale (GDS) with 15 items, as follows: (1) Are you basically satisfied with your life? (reverse coded) (2) Have you dropped many of your activities and interests? (3) Do you feel that your life is empty? (4) Do you often get bored? (5) Are you in good spirits most of the time? (reverse coded) (6) Are you afraid that something bad is going to happen to you? (7) Do you feel happy most of the time? (reverse coded) (8) Do you often feel helpless? (9) Do you prefer to stay at home, rather than going out and doing new things? (10) Do you feel you have more problems with memory than most? (11) Do you think it is wonderful to be alive now? (reverse coded) (12) Do you feel pretty worthless the way you are now? (13) Do you feel full of energy? (reverse coded) (14) Do you feel that your situation is hopeless? (15) Do you think that most people are better off than you are? Responses are binary (yes/no), and the overall summed score ranges from 0 to 15, with higher scores indicating more severe depressive symptoms (Sheikh and Yesavage, 1986). The Japanese version of the GDS has been shown to have good validity and reliability as a screening instrument for major depressive disorder (sensitivity = 0.98, specificity = 0.86, Cronbach's alpha = 0.83) (Sugishita et al., 2017). We used the changes in the score from 2010 to 2013 as a primary continuous outcome.

2.2.2. Exposures

We used five items to assess disaster experiences including housing damage, loss of job, loss of relatives/friends, drop in subjective economic status, and changes in household income. Housing damage (reported in the 2013 follow-up survey) was externally assessed by property inspectors and classified into five levels: (a) no damage, (b) partial, (c) minor, (d) major, and (e) complete destruction. We created a binary variable representing home loss (1 = complete destruction and 0 = no damage/less severe damage). Loss of job was assessed by the question: "Did your work status change because of the disaster?" (1 = "lost job" and 0 = otherwise). We binarized the variables for drop in subjective economic status (1 = "worse" or "a little worse" and 0 = "unchanged", "a little better", or "better"), as well as loss of friends/relatives (1 = yes, 0 = no). Household income was equivalized to account for the differences in household size.

2.2.3. Mediators

Our mediators of interest were post-disaster deterioration in social support and social capital. Respondents were asked to report whether they received emotional and instrumental support from kin relationships (spouse, children living together, children living separately, and relatives) and non- kin relationships (neighbors, friends, and others). The items asked: "Do you have anyone who you can talk to when you have concerns or complaints?" for emotional support and "Do you have anyone who can take care of you when you are sick for a few days?" for instrumental support. We created four categories of social support based on its type and source (i.e., emotional support by kin, emotional support by non-kin, instrumental support by kin, and instrumental support by non-kin). We counted the number of available sources for each type of support, and created a binary variable representing pre/post dis-

Fig. 1. Map of Iwanuma City, Miyagi Prefec-



Fig. 2. Flow of analytical sample selection.

aster deterioration of social support (1 = decreased number of sourcesafter the disaster, 0 =otherwise).

Social capital was assessed by two components; social cohesion and informal socializing/social participation. Social cohesion was assessed by residents' perceptions of trust in the community ("Do you think that people living in your community can be trusted in general?"), levels of mutual help ("Do you think people living in your community try to help others in most situations?"), and community attachment ("How attached are you to the community in which you live?"). Each item was measured on a 5-point Likert scale ranging from 1 (not at all) to 5 (very much).

The informal socializing/social participation aspect of social capital was measured by the frequency of meeting with friends ("How often do you see your friends?" Range: 1, rarely; 6, almost every day), the number of friends whom the respondent met during the past month ("How many friends/acquaintances have you seen over the past month" Range: 1, none; 5, 10 or more), and the frequency of participating in sports and hobby clubs per week ("How often do you attend activities for sports club?" Range: 1, none; 6, almost every day; and "How often do you attend activities for hobby club? Range: 1, none; 6, almost every day). Responses to each item were standardized (mean = 0, standard devia-



Fig. 3. Causal diagram showing relationships between the key variables.

In this study, we first examined (i) the associations between disaster experiences and post-disaster deterioration of social support/social capital (i.e., the exposuremediator associations represented by the arrow A), (ii) the associations between disaster experiences and changes in depressive symptoms (i.e., the exposure-outcome associations represented by the sum of the path $A \rightarrow B$ and the arrow C), (iii) the associations between the post-disaster deterioration of social support/social capital and changes in depressive symptoms (i.e., mediator-outcome associations represented by the arrow B). The subsequent formal causal mediation analysis decomposed the total effect of the disaster-related experiences on changes in depressive symptoms into natural indirect effect (the path $A \rightarrow B$) and the direct effect (the arrow C).

tion =1) and the means of the standardized responses were used as the scores for social cohesion and informal socializing/social participation. We created a binary variable representing pre/post disaster deterioration of social capital (1= decreased score after the disaster, 0 = otherwise).

2.2.4. Covariates

We adjusted for a vector of baseline sociodemographic characteristics as potential confounders, including age (continuous), gender (male vs. female), marital status (non-married (single, widowed or divorced vs. married), years of schooling (9 years or less vs. more than 9 years), and equivalized household income (continuous). Household income was equivalized by dividing annual income by the square root of the household size.

2.3. Statistical analysis

First, we examined; (i) the associations between all of the five disaster experiences and post-disaster deterioration of social support/social capital (i.e., the exposure-mediator associations), (ii) the associations between the five disaster experiences and changes in depressive symptoms (i.e., the exposure-outcome associations), (iii) the associations between the post-disaster deterioration of social support/social capital and changes in depressive symptoms (i.e., mediator-outcome associations) (see Fig. 3 for the causal diagram showing how these analyses are related with one another). We used logistic regression for Analysis (i) and linear regression for Analysis (ii) and (iii). Analyses (i) and (ii) were adjusted for potential confounders, while (iii) was further adjusted for disaster-related experiences as well because these exposures are confounders for the mediator-outcome associations.

Second, we performed causal mediation analysis based on a counterfactual framework using the R package "mediation" (Imai et al., 2010; Tingley et al., 2014). In order to calculate the proportion of the total effect of the exposure on the outcome mediated through the mediator, the total effect was decomposed into natural direct effect (NDE) and natural indirect effect (NIE) (VanderWeele, 2015). Briefly, the NDE is defined as the effect of an exposure had a mediator been set to the value that would have been observed in the absence of the exposure, and the NIE is computed by subtracting the NDE from the total effect, representing the magnitude of the effect of the exposure through the mediator. See Supplementary Text for more detailed description of the method. We examined only the combinations of (a) exposure variables that were associated with the outcomes and (b) mediators that were associated with the exposure variables. This choice was made because performing formal causal mediation analysis is not meaningful when exposures do not have total effects on outcomes and when mediators do not have impacts on outcomes (i.e., lack of potential mediation).

A key strength of the causal mediation analysis is that it allows for exposure-mediator interaction, which conventional approaches for mediation (e.g., Baron and Kenny's product method) cannot deal with (VanderWeele, 2015; Baron and Kenny, 1986). As a sensitivity analysis, we assessed the exposure-mediator interaction by examining whether the associations between post-disaster deterioration of social support/capital and changes in depressive symptoms vary by level of disaster damages. We further performed causal mediation analysis without modeling the exposure-mediator interaction to assess the potential impacts of ignoring the interaction.

Standard errors were computed via bootstrapping with 1000 resampling (Efron and Tibshirani, 1986). We imputed missing data by chained equations and combined the results from the 20 imputed datasets using the R package "MICE" (Buuren and Groothuis-Oudshoorn, 2011).

3. Results

3.1. Descriptive analyses

As shown in Table A.1, the mean baseline age of the study sample was 73.6 years, 43.5% were male. Among them, 4.5% experienced home loss, 26.2% experienced loss of relatives, 15.4% experienced loss of friends, experienced 104,000 Japanese yen (1060 USD as of October 1, 2013) loss of annual income on average, 5.5% lost their jobs, and 23% answered that their economic status deteriorated after the earthquake. Table 1 summarizes the descriptive findings for the sample. Overall, there was a slight increase in depressive symptoms and emotional support received from kin, while other forms of social support and social capital were unchanged. However, this overall trend masks a very distinct pattern among survivors who experienced disaster-related damage. For example, when we examined the changes by home loss status (Table A.2), kin emotional support increased only among people who escaped home loss. On the other hand, among those who suffered home loss, kin instrumental support, non-kin emotional support, and social cohesion all deteriorated, while non-kin instrumental support increased.

3.2. Disaster experiences and deterioration of social support/social capital

Fig. 4 (see Table A.3 for the point estimates and confidence intervals) illustrates the associations between disaster experiences and post-disaster deterioration of social support/social capital. Home loss was associated with higher odds of deterioration of kin emotional support (OR = 1.51; 95% CI: 1.02 to 2.25) and kin instrumental support (OR = 1.77; 95% CI: 1.19 to 2.65), while drop in subjective economic status was associated with deteriorated kin instrumental support only (OR = 1.29; 95% CI: 1.03 to 1.63). However, we did not find comparably strong evidence of associations with deteriorated kin support for other disaster-related experiences.

Turning to non-kin support, loss of relatives (OR = 1.24; 95% CI: 1.02 to 1.52), drop in subjective economic status (OR = 1.35; 95% CI: 1.10 to 1.66), job loss (OR = 1.45; 95% CI: 1.00 to 2.09), and home loss (OR = 1.75; 95% CI: 1.18 to 2.60) were associated with increased odds of emotional support deterioration. We did not find evidence that

Table 1

Changes in depressive symptoms and social support/social capital before and after the disaster onset among the analytical sample (n = 3567).

	2010	2013
GDS Score ^a		
Mean (SD)	3.66 (3.44)	3.78 (3.38)
Missing	493 (13.8%)	468 (13.1%)
Depression (GDS>=5) ^b		
Not Depressed	2090 (58.6%)	2072 (58.1%)
Depressed	984 (27.6%)	1027 (28.8%)
Missing	493 (13.8%)	468 (13.1%)
Number of Sources for Kin Emotional Social Support		
Mean (SD)	1.09 (0.76)	1.29 (0.84)
Missing	142 (4.0%)	0 (0%)
Number of Sources for Kin Instrumental Social Support		
Mean (SD)	1.31 (0.67)	1.28 (0.73)
Missing	98 (2.7%)	98 (2.7%)
Number of Sources for Non-kin Emotional Social Support		
Mean (SD)	0.55 (0.67)	0.57 (0.70)
Missing	142 (4.0%)	142 (4.0%)
Number of Sources for Non-kin Instrumental Social Support		
Mean (SD)	0.11 (0.37)	0.12 (0.37)
Missing	98 (2.7%)	98 (2.7%)
Informal Socializing and Social Participation		
Mean (SD)	0.12 (0.99)	0.00 (1.00)
Missing	717 (20.1%)	220 (6.2%)
Social Cohesion		
Mean (SD)	0.05 (0.95)	0.00 (1.00)
Missing	181 (5.1%)	100 (2.8%)

^a GDS: Geriatric Depression Scale.

Home Loss

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^b GDS was dichotomized using the commonly used cut-off of 5 points or above, indicating clinical depression.



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A: Deterioration of Social Support

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Odds Ratio

Fig. 4. Associations of disaster experiences with A) Deterioration of social support and B) Social capital. Logistic regression models were adjusted for potential confounders including baseline age, gender, marital status, education, and household income.



Fig. 5. Associations with changes in depressive symptoms for A) Disaster experiences and B) Deterioration of social support and social capital.A) Linear regression models were adjusted for potential confounders including baseline age, gender, marital status, education, and household income.B) Linear regression models were adjusted for potential confounders including baseline age, gender, marital status, education, household income, and disaster experiences.

Table 2

Causal effect decomposition of total effect of disaster-induced experiences on changes in depressive symptoms mediated through post-disaster deterioration of social support and social capital^{a,b,c}.

Exposure	Mediator	Total effect		Natural indirect effect		Natural direct effect		PM ^d
		Coef.	(95% CI)	Coef.	(95% CI)	Coef.	(95% CI)	%
Home Loss	Kin Emotional Support	1.11	(0.66 to 1.58)	-0.04	(-0.16 to 0.03)	1.15	(0.70 to 1.56)	-3.60
	Kin Instrumental Support	1.07	(0.58 to 1.50)	-0.06	(-0.21 to 0.04)	1.12	(0.61 to 1.64)	-5.61
	Non-kin Emotional Support	1.02	(0.57 to 1.56)	-0.02	(-0.15 to 0.09)	1.04	(0.57 to 1.63)	-1.96
	Social Cohesion	1.02	(0.56 to 1.51)	0.03	(-0.10 to 0.21)	0.99	(0.55 to 1.46)	2.94
Loss of Job	Kin Instrumental Support	0.66	(0.35 to 1.12)	0.01	(-0.03 to 0.06)	0.65	(0.32 to 1.11)	1.52
	Non-kin Emotional Support	0.65	(0.26 to 1.15)	0.04	(-0.02 to 0.11)	0.61	(0.24 to 1.09)	6.15
	Social Cohesion	0.69	(0.23 to 1.07)	0.003	(-0.06 to 0.05)	0.69	(0.24 to 1.04)	0.43
Subjective Economic Status	Kin Instrumental Support	0.24	(-0.03 to 0.49)	0.01	(-0.02 to 0.04)	0.24	(-0.04 to 0.49)	4.17
	Non-kin Emotional Support	0.25	(-0.01 to 0.44)	0.03	(0.01 to 0.08)	0.21	(-0.05 to 0.40)	12.00
	Informal Socializing	0.25	(0.03 to 0.48)	0.02	(0.00 to 0.05)	0.24	(0.01 to 0.45)	8.00
	Social Cohesion	0.25	(0.07 to 0.45)	0.02	(0.00 to 0.05)	0.23	(0.05 to 0.44)	8.00

^a Depressive symptoms were measured by Geriatric Depression Scale (the scale score ranges 0–15 where higher score indicates more depressive symptoms) and changes in the score between 2010 and 2013 were analyzed as a primary outcome.

^b Models were adjusted for potential confounders including baseline age, gender, marital status, education, and household income.

^c Counterfactual-based causal mediation analysis modeling the exposure-mediator interaction was used for effect decomposition.

^d Proportion mediated (PM) was computed by dividing a natural indirect effect by a total effect.

the disaster experiences were associated with deterioration of non-kin instrumental support.

Turning to social capital, drop in subjective economic status was associated with deteriorated informal socializing (OR = 1.21; 95% CI: 0.98 to 1.48), while drop in subjective economic status (OR = 1.21; 95% CI: 1.02 to 1.44) and home loss (OR = 2.08; 95% CI: 1.42 to 3.04) were associated with deteriorated social cohesion.

Changes in Depressive Symptoms and Disaster Experiences and Deterioration of Social Support /Social Capital

Fig. 5 (see Table A.4 for the point estimates and confidence intervals) summarizes exposure-outcome associations and mediator-outcome associations. For the exposure-outcome associations, there was greater increase in depressive symptoms after the disaster among those who experienced drop in subjective economic status (estimate = 0.44; 95% CI: 0.14 to 0.75), loss of job (estimate = 0.74; 95% CI: 0.29 to 1.18), and home loss (estimate = 1.46; 95% CI: 0.85 to 2.07). For the mediator-

outcome associations, deterioration of kin social support and social capital measures were significantly associated with greater increases in depressive symptoms.

3.3. Causal effect decomposition of total effect of disaster-induced experiences

Table 2 shows the result from causal effect decomposition of total effect of the disaster-induced experiences on changes in depressive symptoms mediated through post-disaster deterioration of social support/social capital. We examined only the combinations of the exposures and mediators for which potential mediation was indicated by the previous analyses, and we modeled exposure-mediator interaction in the causal mediation analysis. For the total effect of loss of job and home loss on changes in depressive symptoms, there was no clear evidence of indirect effect mediated through post-disaster deterioration of social



Fig. 6. Associations between deterioration of social support/social capital and changes in depressive symptoms by presence of disaster damage. Models were adjusted for potential confounders including baseline age, gender, marital status, education, household income, and other disaster experiences.

support/social capital. For the total effect of subjective economic status, there was some evidence of mediation by post-disaster deterioration of social support/social capital although its magnitude was small (4-12%).

As shown in Fig. 6, the associations between social support/capital deterioration and greater increase in depressive symptoms was more evident among people *without* disaster damages compared to those with the damages, suggesting the presence of exposure-mediator interaction. The result of causal mediation analysis ignoring the exposure-mediator interaction is shown in **Table A.5.** The magnitude of the indirect effects increased and there appeared to be some evidence of small but significant indirect effects for home loss and loss of job after ignoring the interaction.

We also performed sensitivity analyses using different cut-offs for the housing damage variable to examine whether the extent of mediation by social support/capital deterioration changes. Specifically, we created the following two variables; (a) complete destruction/major damage vs less severe/no damage and (b) major damage vs less severe/no damage (we excluded those who reported complete destruction). The results did not materially affect our conclusion regarding mediation of housing damage by social support/capital deterioration (Data available from authors on request).

4. Discussion

4.1. Deterioration of social support within 3 years after the disaster

We found evidence that specific categories of disaster-related damage, particularly home loss, were associated with deterioration of social support/social capital after the disaster. Surprisingly, for the overall Iwanuma sample, emotional support *went up* between 2010 and 2013. However, there was a qualitative difference in the pattern of changes in social support according to the presence of disaster damages. Notably, people who lost their homes reported decreased kin and non-kin emotional support, but increased non-kin instrumental support, while people who did not suffer home loss reported an *increase* in kin emotional support. There are plausible explanations for the divergent patterns we observed. For example, people whose homes were destroyed ended up moving into temporary housing or relocating to rental housing in a different neighborhood. We have previously reported that survivors who were moved to temporary trailer homes experienced a decrease in social cohesion, particularly if they were resettled randomly, i.e., moved into the trailer homes without regard for preserving social relationships between neighboring houses that existed prior to the disaster (Hikichi et al., 2017). These residential moves may have disrupted patterns of emotional support exchange in people's lives. At the same time, those who suffered complete home loss were also more likely to be receiving instrumental support 2.5 years after the disaster, in the form of public assistance. However, we also find some evidence of *exhaustion* of instrumental support received from kin members, in line with the predictions of the social support deterioration model.

4.2. Increase in depressive symptoms 3 years after the disaster

As demonstrated in the previous study using Iwanuma data (Tsuboya et al., 2016), home loss, job loss and reduction of subjective economic status were each associated with greater increases in depressive symptoms after the disaster. However, we did not find strong evidence for an association between loss of relatives/friends and depressive symptoms in this study, which is contrary to previous findings (Thoresen et al., 2019). One possible interpretation is that after an initial period of grief, people have recovered from the loss of loved ones at the three year mark, while continuing struggles/worries about the economic damage wrought by the disaster loom larger in the daily lives of survivors. Moreover, the age of the study participants in the Iwanuma Study (mean: 73.6 years) meant that the death of relatives/friends might have been a more normative experience for them, and hence did not have as lasting an impact on their depressive symptoms. We also found that post-disaster deterioration of social support/social capital was generally associated with greater increases in depressive symptoms after the disaster. The link between post-disaster changes in social capital and depressive symptoms was also reported in the aftermath of the 2016 Kumamoto earthquake in Japan (Sato et al., 2020).

4.3. Does social support deterioration mediate the association between disaster experiences and depressive symptoms?

A central claim of the social support deterioration model is that a decline in social support (following a "honeymoon" phase immediately after the disaster) actively contributes to the decline in mental health among disaster survivors. Our findings provide some support for deterioration in kin-based emotional/instrumental support as well as non-kin emotional support among people who suffered home loss and job loss. However, our causal mediation analysis suggested little mediation of the association between disaster damage and depressive symptoms by social support/social capital deterioration.

A possible explanation for this finding is the presence of an exposuremediator interaction; contrary to the support deterioration model, social support deterioration appeared to be more detrimental among people *who escaped disaster* damage. One possible reason for this is that people who suffered severe disaster damage had more extreme psychological distress – to an extent that social support/capital had less of an impact in mitigating their symptoms compared to the general population.

When the exposure-mediator interaction was removed from the model, we saw small but significant mediation for the total effect of loss of job and home loss, suggesting that ignoring the exposure-mediator interaction in mediation analysis would result in biased estimates of the indirect effect; specifically, the indirect effect would be overestimated when the mediator had less impacts on the outcome when the exposure is present. Previous studies of the social support deterioration model may have over-estimated the extent of mediation as a result of ignoring potential exposure-mediator interactions (Kaniasty and Norris, 1993; Norris and Kaniasty, 1996; Taft et al., 1999; Vranceanu et al., 2007; Yap and Devilly, 2004).

The results overall suggest that social support deterioration after the disasters had detrimental effects on depressive symptoms of survivors, but there appeared to be other pathways linking disaster-related experiences and depressive symptoms. Notably, our finding that there was little evidence of *mediation* by post-disaster social support deterioration does not take away from the potential significance of social support and social capital in the recovery process that have previously been reported (Tsuboya et al., 2016; Sasaki et al., 2020). It also leaves open the possibility that deterioration in social support could mediate the association of disaster damage with other health outcomes, such as cognitive decline (Hikichi et al., 2016). The policy implication of the exposure-mediator interaction is that offering social support alone may not suffice to help disaster survivors experiencing extreme distress to maintain their mental health.

4.4. Limitations

There are several limitations in this study. First, selective attrition due to non-participation in the follow-up survey may have resulted in selection bias. When the disaster experiences increase the likelihood of censoring (e.g., non-participation due to post-traumatic stress disorder) and censoring and changes in depressive symptoms share common causes such as pre-existing health problems, the selection bias would lead to underestimation of the effect of an exposure. Second, causal mediation analysis requires a set of fairly strong assumptions of no unmeasured confounders for: 1) exposure-outcome relationship, 2) mediator-outcome relationship, and 3) exposure-mediator relationship. Although we leveraged the natural experiment data to account for a rich set of baseline characteristics, the assumptions cannot be guaranteed. Third, our measure of instrumental social support was based on a single item about the availability of care if the respondent became sick. Unfortunately, we lacked a more comprehensive set of items such as cash loans and helping with other chores. Fourth, this study assessed depressive symptoms approximately 2.5 years after the disaster onset and did support the social support deterioration model. However, postdisaster deterioration of social support and social capital may mediate the adverse effects of disaster experiences on depressive symptoms with a longer follow-up. Fifth, although the relationships between disaster experiences, social support/social capital deterioration, and depressive symptoms might vary across geographic areas, we focused on assessing average effects due to lack of space. Future studies on this spatial heterogeneity are warranted. Lastly, as we used the relatively unique sample of older adult survivors living in Iwanuma after the Japanese earthquake and tsunami, the findings may not be generalizable to other populations with different cultural backgrounds. For instance, if it turns out that Japanese society is characterized by higher levels of social norms of mutual assistance compared to western settings, we might expect the extent of post-disaster deterioration of social support/capital (i.e., the exposure-mediator relationship) - and, consequently, the total effect of disaster-related damage - may be smaller in our sample. However, it is difficult to predict the impact on the magnitude of the indirect effect relative to the total effect (i.e., proportion mediated) which could either increase or decrease.

5. Conclusion

We found little evidence that post-disaster deterioration of social support and social capital mediated the effects of traumatic experiences from the 2011 Great East Japan Earthquake on depressive symptoms 2.5 year after the onset among older survivors in Iwanuma. Lack of empirical support for the social support deterioration model may be, at least partly, attributable to the presence of exposure-mediator interactions.

Declaration of Competing Interest

None.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.wss.2020.100006.

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