Original Article

Predictors of persistent sleep problems among older disaster survivors: a natural experiment from the 2011 Great East Japan earthquake and tsunami

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Abstract

Study Objectives: To examine prospectively the associations of disaster experiences and social support with sleep problems in older adults.

Methods: Data came from a natural experiment caused by the 2011 Great East Japan earthquake and tsunami. Participants in an ongoing prospective cohort (3547 Japanese individuals aged 65 years or older) were inadvertently exposed to the disaster due to their residential location (Iwanuma city) after the 2010 baseline survey. We conducted a follow-up survey in 2013 to inquire about disaster-related experiences and short sleep duration, sleep insufficiency, poor sleep quality, insomnia symptoms, and sleep medication use. Poisson regression models adjusted for baseline socio-demographic and lifestyle covariates.

Results: Financial hardship predicted increased risks of short sleep duration (relative risk [RR] = 1.40; 95% confidence interval [CI] [1.03, 1.90]), sleep insufficiency (RR = 1.29; 95% CI [1.01, 1.66]), poor sleep quality (RR = 1.47; 95% CI [1.26, 1.70]), and insomnia symptoms (RR = 1.13; 95% CI [1.01, 1.28]). Home destruction predicted sleep medication use while health care disruption predicted poor sleep quality. Loss of close relatives or friends did not predict any sustained sleep problems. Additionally, having instrumental support reduced risks of all sleep problems while having emotional support reduced risk of poor sleep quality.

Conclusions: Approximately 2.5 years after the disaster, older survivors' sleep problems were more durably linked to material aspects of disaster damage than to loss of loved ones. Findings could inform targeted recovery efforts for groups with greatest need to promote older survivors' sleep health and overall well-being.

Statement of Significance

Sleep problems are among the most prevalent, yet understudied, health concerns of disaster survivors. We investigated prospective determinants of sleep problems among older survivors. Data from a natural experiment in Japan allowed us to evaluate the unique associations of different types of disaster damage and social support with several dimensions of sleep. Sleep problems were predicted by material impacts of disaster damage, but not loss of close relatives or friends (from which survivors seemed to have recovered). Instrumental support was more relevant to sleep problems than emotional support. Findings could inform interventions to alleviate survivors' sleep problems and subsequent health outcomes, which could assist in disaster preparedness and recovery. Future research should explore the associations using objective measures of sleep.

Key words: disaster; social support; sleep; natural experiment; older adults; survivors; Japan

Introduction

In recent decades, accompanying the rising incidence of natural disasters and increasing population growth and population density, the scale and scope of disaster damage have increased notably [1–3]. About 278 million people were affected by natural disasters in 1990, as compared to 332 million in 2011 [2]. Sleep is one of the most common health concerns of disaster survivors. Approximately half of the victims in Santa Rose Island continued to experience sleep disturbances 6 days after Hurricane Ivan (a Category 3 storm) [4]. Such sleep consequences of disaster exposure are not simply transient. One year after the 1999 Athens earthquake in Greece, 55% of the survivors developed sleep disorders [5]. Short sleep duration, poor sleep quality, or both has been associated with chronic diseases (e.g. type 2 diabetes and cardiovascular diseases) and mortality in various populations [6–17]. Sleep disturbances have also been linked to mental health problems such as depression, perceived stress, and post-traumatic stress disorder, particularly among disaster-affected populations [18–22].

Given the high prevalence of sleep problems and their extensive subsequent health effects on disaster survivors, it is essential to deepen our understanding of survivors' sleep. Identifying factors that contribute to survivors' sleep problems is critical for developing effective interventions to mitigate survivors' sleep problems and the associated adverse health outcomes, which would assist in disaster preparedness and recovery efforts to promote reconstruction and community resilience after disaster.

In contrast to the wealth of evidence on the persistent mental health effects of disaster experiences [23–31], very little has been published on survivors' lingering sleep problems during the disaster recovery phase, particularly among older adults. Initial studies on determinants of survivors' sleep health have documented the importance of exposure to disaster [32–35]. These studies, while suggestive, are far from comprehensive. The usual absence of a comparable control group (unexposed to the disaster) hinders appropriate counterfactual comparisons. Moreover, much of previous research has included only one measure of sleep (such as sleep duration [33] or sleep quality [32]), and has addressed exposure to disaster as a general experience without differentiating between types of disaster damage or has only considered home destruction [32–35]. Furthermore, prior research on predictors of disaster survivors' sleep has investigated younger populations with relatively short follow-ups (usually less than 1 year) [32–35], but not older adults who are disproportionately affected by disasters [36, 37].

On the other hand, some studies have suggested that lack of social support is associated with increased risks of sleep problems [38–42]. However, the cross-sectional design employed by prior studies constrains their ability to identify causality and renders their results to recall bias because the information about social support was gathered in the aftermath of a disaster. There has not yet been a study on survivors' sleep in which pre-disaster social support information was used.

This study aims to advance this line of research by examining prospectively whether disaster damage and social support are associated with persistent sleep problems among older survivors of the 2011 Great East Japan earthquake and tsunami over 2.5 years of follow-up. It leverages a prospective study design – a natural experiment afforded by the JApan Gerontological Evaluation Study (JAGES) of community-dwelling adults aged 65 or older, as the 2011 disaster struck one of the field sites, Iwanuma city, between the baseline (2010) and the follow-up (2013) surveys. We evaluate multiple dimensions of sleep, including short sleep duration, sleep insufficiency, poor sleep quality, insomnia symptoms, and sleep medication use, to fully examine how disaster damage and social support are linked to a variety of sleep behaviors.

The primary aim is to determine the unique impacts of different types of disaster damage (financial hardship, home destruction, health care disruption, and loss of close relatives or friends) on sleep problems. We hypothesize that each type of disaster damage would predict higher risk of each sleep problem among older survivors in tsunami-affected areas over 2.5 years of follow-up. For instance, experiencing financial hardship would predict higher risk of short sleep duration at follow-up. The secondary aim is to evaluate the influences of instrumental support (help, aid, or assistance with tangible needs) and emotional support (the expression of empathy, reassurance, or trust) [43] on sleep. We hypothesize that availability of each form of social support would be associated with better sleep over 2.5 years of follow-up.

Methods

Study participants and study design

This paper used data collected as part of a national cohort study, the JAGES project, which was established in August 2010 to assess prospective predictors of disability onset among community-dwelling older adults in Japan. The municipal health authorities are responsible for maintaining accurate registers of every citizen residing in their catchment areas in Japan. A census of all residents aged 65 years or older was conducted and the baseline questionnaire was mailed to every citizen in the age range in 31 towns and cities across the country, using the official residential registry system (koseki touhon) provided by the city town hall as the sampling frame. Out of 169 215 older adults invited, 112 123 eligible individuals responded to the survey, yielding a response rate of 66.3%. The survey asked questions on participants' socio-demographics, lifestyle habits, social support, as well as health behaviors and outcomes [30].

Seven months after the baseline survey, one of the field sites of JAGES, Iwanuma city, was directly struck by the 2011 Great East Japan earthquake and tsunami on March 11. The disaster killed 187 residents (out of a total population of 44 187), damaged 5428 buildings, and inundated 48% of Iwanuma land area (Figure 1) [30, 44]. The research team obtained permission from the local government to repeat the survey in 2013. A follow-up survey was conducted among survivors in the city approximately 2.5 years after the disaster (October 2013 to January 2014), which inquired about participants' experiences both during and after the disaster. 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.

Figure 2 depicts study recruitment and retention. At baseline, invitations were sent to all residents aged 65 years or older in Iwanuma city. Five-thousand fifty-eight individuals agreed to participate (out of 8576, participation rate: 59.0%). Among 4380 participants eligible for the follow-up study, 3594 completed the survey (follow-up rate: 82.1%). After excluding 27
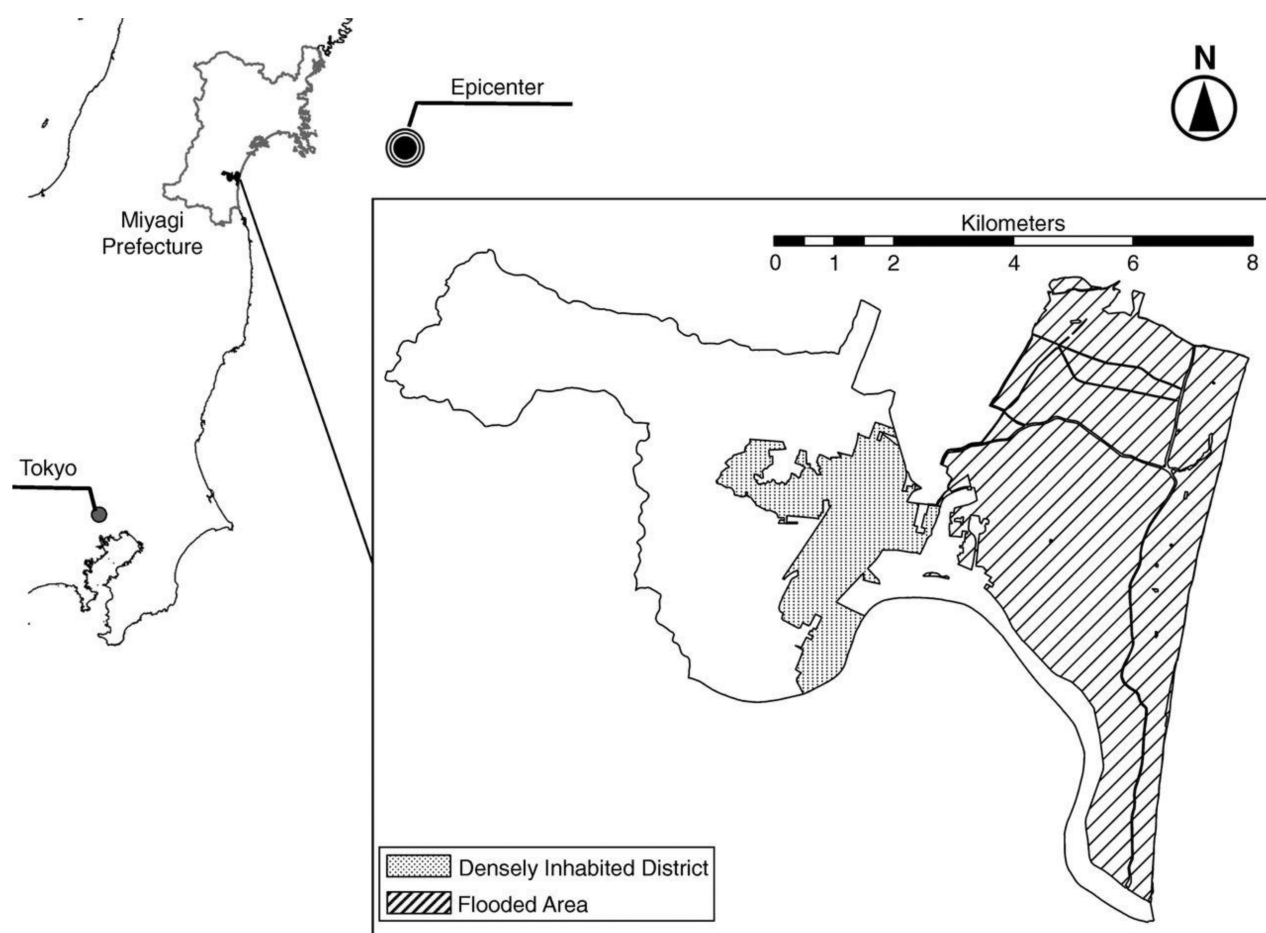
Figure 1. Map of Iwanuma, in which 187 people died or are missing, 5428 buildings were damaged, and 48% of the area was flooded, Japan. Reproduced from ref. [30].

respondents with incompletely signed informed consent forms and 20 respondents who reported erroneous (>24 hours) or extreme sleep duration (<3 hours or >13 hours), the analytic panel sample consisted of 3547 individuals.

Assessment of outcomes

Post-disaster assessment of sleep

Five indicators of sleep problems were included: short sleep duration, sleep insufficiency, poor sleep quality, insomnia symptoms, and sleep medication use. The questions were derived from the Pittsburgh Sleep Quality Index (PSQI) [45] except for the item on sleep insufficiency. The survey had only these sleep-related questions but not the whole PSQI scale, which restricted our ability in examining an overall sleep quality score. However, looking at the variety of sleep indicators granted us the opportunity to assess how disaster damage and social support were associated with different aspects of self-reported sleep.

Sleep duration was determined by asking how many actual hours of sleep respondents got in the past month (PSQI #4a). *Short sleep duration* was defined as sleeping 5 hours or less per day. The cut-point was chosen because previous studies have shown that sleeping 5 hours or less is associated with elevated risk of mortality among older populations [46–48]. The National Sleep Foundation also recommends older adults aged 65 years or older not to sleep less than 5 hours as it is not likely conductive for health and well-being [49].

Insomnia symptoms were assessed by asking how often respondents "could not fall asleep within half an hour of going to bed" (PSQI #5a) or "woke up in the middle of the night or early in the morning" (PSQI #5b), with response categories of never, less than once a week, one to two times a week, and three or more times a week. Respondents who experienced the symptoms three or more times a week were regarded as suffering from insomnia. The variable was dichotomized as having the symptoms more frequently might indicate more severe sleep problems and indicate more clinical significance because experiencing insomnia most of the time has been shown to be associated with increased risk of mortality [50].

Sleep insufficiency was defined as experiencing the symptom of "didn't feel well-rested when woke up in the morning in the past month" 3 or more times a week [51, 52]. The item is similar to the Centers for Disease Control and Prevention (CDC) surveillance for state-level sleep insufficiency [53].

Sleep quality was measured by asking respondents to rate their *sleep quality* as a whole in the past month (PSQI #6), with responses ranging from 1 (very poor) to 4 (very good). A response of 1 (very poor) or 2 (poor) indicated *poor sleep quality*.

Sleep medication use was defined as taking medication (that was prescribed by a doctor or bought at a pharmacy or other vendors) to help sleep (PSQI #7).

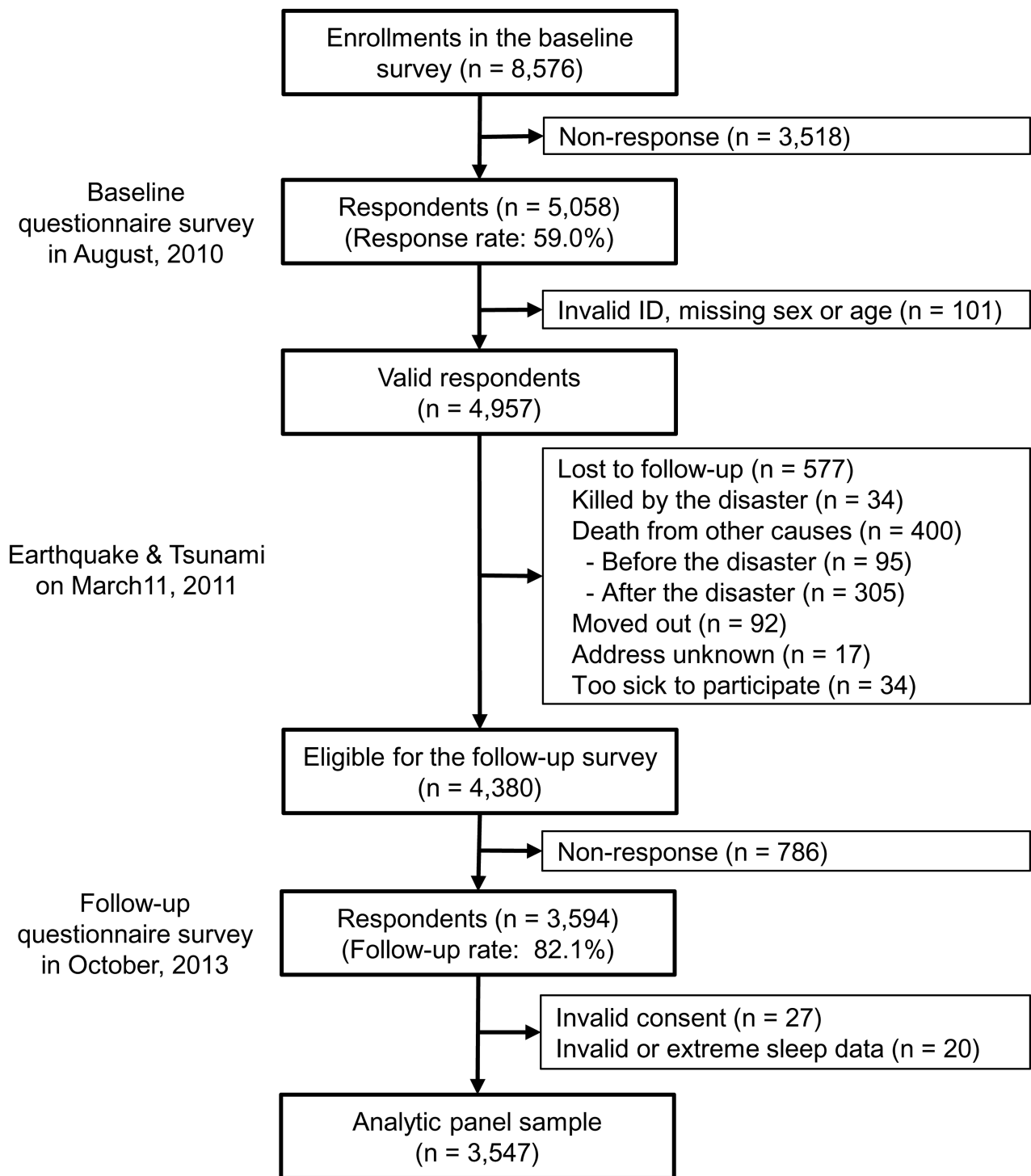Each sleep indicator was binary and was analyzed separately.

Figure 2. Flow chart of the sample.

Assessment of Exposures

Post-disaster assessment of disaster damage

The main exposures of interest were types of disaster damage (primary aim) and types of pre-disaster social support (secondary aim). *Disaster damage* was measured by a series of questions asking the respondents their disaster-related experiences. *Financial hardship* was assessed by asking respondents if their financial conditions changed after the earthquake. Those who reported "worse" or "much worse" financial conditions were defined as experiencing financial hardship. *Home destruction* was measured by asking how badly respondents' residences were damaged in the earthquake, with responses categorized into three levels (0 = no damage, 1 = partially destroyed, and 2 = half destroyed or worse). *Health care disruption* was defined as "unable to receive a medical examination because of the earthquake." *Loss of close relatives or friends* was defined by asking the question "Did you lose a close relative or friend in the earthquake?" All damage variables were binary except for home destruction.

Pre-disaster assessment of social support

Two dimensions of *social support* was measured at baseline: instrumental and emotional support. *Instrumental support* was assessed by asking the question "Do you have someone who looks after you when you are sick and confined to a bed for a few days?" *Emotional support* was assessed by asking if the respondent had someone who listened to his/her concerns and complaints. Both social support variables were binary.

Covariates

Pre-disaster assessment of covariates

We controlled for respondents' pre-disaster socio-demographic and lifestyle characteristics, which have been found to be important for sleep in prior research (see, e.g. ref. [54–56]). Adjusted covariates included gender, age, marital status, educational attainment, and equivalised income, as well as smoking and drinking status. We did not control for depressive symptoms as prior research has indicated that sleep problems are symptoms of and might be risk factors of depression [57]. Including depressive symptoms in the analyses might introduce the problem of over-control.

Statistical Analyses

For the main analyses, we conducted multiple Poisson regression analyses based on models of the form:

$$log(P(Sleep_{post} = 1)) = \beta_0 + DD\beta^{DD} + SS_{pre}\beta^{ss_{pre}} + X_{pre}\beta^{x_{pre}} \quad (1)$$

where $sleep_{post}$ is the post-disaster sleep problem indicator. The coefficient vector β^{DD} captures the effects of disaster damage (DD), including financial hardship, home destruction, health care disruption, and loss of close relatives or friends (primary aim); $\beta^{ss_{pre}}$ captures the effects of pre-disaster social support (SS_{pre}), including instrumental and emotional support (secondary aim); $\beta^{x_{pre}}$ captures the effects of pre-disaster covariates (X_{pre}), including socio-demographic and lifestyle variables.

We used Poisson regression instead of logistic regression as the former provides relative risks (RRs), which some have argued are easier to interpret compared to odds ratios [58]. In addition, the odds ratio is often interpreted as if it were the risk ratio, although the odds ratio approximates the risk ratio only under certain conditions. The more frequent the outcome, the more odds ratio overestimates the RR when it is more than 1 or underestimates it when it is less than 1 [59]. To estimate 95% confidence intervals (CIs) and Wald-based *p*-values we used the robust sandwich estimator of the variance [58].

In supplementary analyses, we addressed the issue of missingness by applying multiple imputation with the chained equations to the main analyses (10 imputed datasets), under the assumption of missing at random. Multiple imputation uses the distribution of the observed data to estimate a set of plausible values for the missing data, incorporating random components to reflect uncertainty. Multiple (10) datasets were created and then analyzed individually but identically to obtain a set of parameter estimates, which were later combined to calculate the overall estimates, variances, and CIs [60].

All analyses were performed using STATA (version 14.0, StataCorp LP, College Station, TX). All tests were two-sided, with a significance level of 5%.

Results

Table 1 presents the descriptive traits of the Iwanuma cohort. As for pre-disaster socio-demographic and lifestyle characteristics, slightly more than half of the respondents were female. About 60% were between the ages of 65 and 74 while the rest were older. Approximately two-thirds of the participants were married. Thirty-six percent received less than 9 years of education or less. About half had an equivalised income below 2 million JPY. Participants who had never smoked and who had never consumed alcohol accounted for 61.2% and 59.9% of the sample, respectively. With respect to exposures of interest, 96.0% of the respondents reported having pre-disaster instrumental support and 93.8% emotional support. Twenty-four percent of the respondents experienced financial hardships after the disaster. Home destruction was the most prevalent type of disaster damage: 15.8% reported home being half destroyed or worse and 43.1% reported home being partially destroyed. Thirteen percent of the respondents experienced health care disruption and 37% experienced loss of close relatives or friends. In terms of sleep problems, the percentage of people experiencing insomnia symptoms was the highest (41.4%), followed by poor sleep quality (27.0%), sleep medication use (21.6%), sleep insufficiency (13.4%), and short sleep duration (8.7%).

Table 2 reports results from Poisson regression models separately estimating short sleep duration, sleep insufficiency, poor sleep quality, insomnia symptoms, and sleep medication use. Financial hardship predicted the majority of sleep problems. It was significantly associated with higher risks of short sleep duration (RR = 1.40; 95% CI [1.03, 1.90]), sleep insufficiency (RR = 1.29; 95% CI [1.01–1.66]), poor sleep quality (RR = 1.47; 95% CI [1.26–1.70]), and insomnia symptoms (RR = 1.13; 95% CI [1.01–1.28]), after adjusting for pre-disaster socio-demographic, lifestyle, and social support variables. Home destruction was significantly linked to sleep medication use (half destroyed or worse vs. no damage: RR = 1.36; 95% CI [1.06–1.74]; partially destroyed vs. no damage: RR = 1.37; 95% CI [1.15–1.63]). Health care disruption was significantly tied to poor sleep quality (RR = 1.34; 95% CI [1.13–1.58]). Surprisingly, loss of close relatives or friends was not significantly associated with any indicators of sleep problems. With respect to pre-disaster social support, having instrumental support significantly protected the older adults from short sleep duration (RR = 0.57; 95% CI [0.34–0.98]), sleep insufficiency (RR = 0.46; 95% CI [0.31–0.69]), poor sleep quality (RR = 0.63; 95% CI [0.48–0.82]), insomnia symptoms (RR = 0.70; 95% CI [0.57–.087]), and sleep medication use (RR = 0.70; 95% CI [0.49–0.99]). Emotional support significantly protected the older adults from poor sleep quality (RR = 0.74; 95% CI [0.58–0.95]).

As loss of close relatives or friends was correlated with financial hardship ($r = 0.16$; $p < .001$) and with home destruction ($r = 0.13$; $p < .001$), we evaluated whether the nonsignificant relationships between loss of close relatives or friends and the sleep outcomes were due to collinearity across the disaster-related factors by removing the other disaster damage variables from the regression models. Results from the simplified regression models were similar to those from the full model in that loss of close relatives or friends was not significantly associated with any sleep indicators.

We conducted a series of sensitivity analyses by adopting different coding strategies for the sleep variables. First, we adopted a 6-hour cutoff for short sleep duration and reran the regression model so that the results could be compared to studies

Table 1. Descriptive traits of Iwanuma cohort (*n* = 3547)

Variables	N	%	Variables	N	%
Pre-disaster socio-demographics			Disaster damage		
Gender			Financial hardship		
Male	1542	43.5%	Yes	821	23.7%
Female	2005	56.5%	No	2640	76.3%
Age			Home destruction		
65–74 years	2122	59.8%	Half destroyed or worse	543	15.8%
75 years or older	1425	40.2%	Partially destroyed	1487	43.1%
Marital status			No damage	1417	41.1%
Married	2445	71.4%	Health care disruption		
Unmarried	981	28.6%	Yes	453	12.8%
Education			No	3094	87.2%
<6 years	45	1.3%	Loss of close relatives/friends		
6–9 years	1174	34.4%	Yes	1321	37.2%
10–12 years	1484	43.5%	No	2226	62.8%
>12 years	709	20.8%	Post-disaster sleep problems		
Equivalised income			Short sleep duration		
< 2 million JPY	1413	48.8%	Yes	302	8.7%
2–4 million JPY	1200	41.4%	No	3168	91.3%
>4 million JPY	284	9.8%	Sleep insufficiency		
Pre-disaster lifestyle			Yes	462	13.4%
Smoking status			No	2979	86.6%
Current	363	11.2%	Poor sleep quality		
Used to	898	27.6%	Yes	942	27.0%
Never	1990	61.2%	No	2541	73.0%
Drinking status			Insomnia symptoms		
Current	1272	36.7%	Yes	1448	41.4%
Used to	119	3.4%	No	2052	58.6%
Never	2075	59.9%	Sleep medication use		
Pre-disaster social support			Yes	753	21.6%
Instrumental support			No	2732	78.4%
Yes	3314	96.0%			
No	137	4.0%			
Emotional support					
Yes	3196	93.8%			
No	212	6.2%			

that used a 6-hour cutoff. The direction of the effect of financial hardship on short sleep duration was the same as that in the main analyses (5-hour cutoff), but it was no longer statistically significant with a *p*-value of .109 (RR = 1.15; 95% CI [0.97, 1.36]). The effect of instrumental support (RR = 0.74, 95% CI [0.56, 0.98]) remained in the same direction as that in the main analyses and stayed statistically significant. We also did sensitivity analyses modeling the sleep outcomes as continuous variables using linear regression. The substantive conclusions were unchanged in that material aspects of disaster damage were associated with more sleep problems and social support protected people from sleep problems. We further explored the relationships between post-disaster sleep and predictors of interest by constructing a global sleep score from the sleep indicators. A continuous composite sleep score was calculated by summing the responses of the sleep indicators (sleep duration categorized following PSQI scoring guidelines), with higher values indicating worse sleep health. The results were consistent with our main analyses in that financial hardship, home destruction, and health care disruption were significantly associated with worse global sleep health and instrumental support was significantly associated with better global sleep health.

Additionally, we reran the insomnia regression models looking at sleep onset insomnia (could not fall asleep within half an hour of going to bed) and sleep maintenance insomnia (woke up in the middle of the night or early in the morning) separately. While the directions of the effects of financial hardship on sleep onset/maintenance insomnia were the same, financial hardship was only significantly associated with sleep onset insomnia (RR = 1.33, 95% CI [1.07, 1.65]) but not sleep maintenance insomnia (RR = 1.07, 95% CI [.94, 1.23]). The findings suggested that individuals who had trouble falling asleep were more vulnerable to financial hardship compared to those who had trouble maintaining sleep.

The main analyses used data from observations with complete information on all variables included, which was about 70% of the panel (e.g. 2477 out of 3547 participants with complete information in the short sleep duration model). The supplementary analyses, in which we used multiple imputation to address missing data, spoke to the robustness of the study findings in the main analyses. The directions of the effects of disaster damage and social support were the same, and the statistical significance levels remained largely unchanged (Supplementary Table S1).

Table 2. Poisson regression models estimating persistent sleep problems

	Short sleep duration		Sleep insufficiency		Poor sleep quality		Insomnia symptoms		Sleep medication use	
	RR	[95% CI]	RR	[95% CI]	RR	[95% CI]	RR	[95% CI]	RR	[95% CI]
Disaster damage										
Financial hardship (vs. no)	**1.40**	**[1.03, 1.90]***	**1.29**	**[1.01, 1.66]***	**1.47**	**[1.26, 1.70]***	**1.13**	**[1.01, 1.28]***	1.08	[0.88, 1.31]
Home destruction (vs. no)										
Half destroyed or worse	0.82	[0.52, 1.27]	0.98	[0.70, 1.37]	0.90	[0.73, 1.11]	0.99	[0.84, 1.16]	**1.36**	**[1.06, 1.74]***
Partially destroyed	1.13	[0.85, 1.50]	1.20	[0.96, 1.50]	1.12	[0.97, 1.29]	1.09	[0.98, 1.20]	**1.37**	**[1.15, 1.63]***
Health care disruption (vs. no)	1.07	[0.73, 1.58]	1.04	[0.75, 1.42]	**1.34**	**[1.13, 1.58]***	1.08	[0.93, 1.24]	1.14	[0.91, 1.42]
Loss of close relatives/friends (vs. no)	1.07	[0.83, 1.39]	1.14	[0.92, 1.40]	1.06	[0.93, 1.21]	0.97	[0.88, 1.07]	0.95	[0.81, 1.12]
Pre-disaster social support										
Instrumental support (vs. no)	**0.57**	**[0.34, 0.98]***	**0.46**	**[0.31, 0.69]***	**0.63**	**[0.48, 0.82]***	**0.70**	**[0.57, 0.87]***	**0.70**	**[0.49, 0.99]***
Emotional support (vs. no)	0.97	[0.54, 1.73]	0.89	[0.59, 1.35]	**0.74**	**[0.58, 0.95]***	1.00	[0.83, 1.22]	1.22	[0.80, 1.87]
Pre-disaster covariates										
Female (vs. male)	1.27	[0.80, 2.01]	0.98	[0.72, 1.34]	1.32	[1.07, 1.64]**	0.94	[0.81, 1.10]	2.18	[1.66, 2.87]***
Age, years	0.98	[0.96, 1.01]	1.02	[1.00, 1.04]+	1.00	[0.99, 1.01]	1.02	[1.01, 1.03]***	1.04	[1.02, 1.05]***
Married (vs. no)	0.70	[0.50, 0.99]*	0.91	[0.71, 1.17]	1.03	[0.87, 1.22]	1.01	[0.89, 1.15]	1.03	[0.85, 1.24]
Education (vs. 10–12 years)										
<6 years	0.31	[0.04, 2.32]	0.73	[0.27, 1.97]	1.21	[0.74, 1.99]	1.14	[0.79, 1.66]	1.13	[0.68, 1.89]
6–9 years	0.92	[0.68, 1.25]	0.91	[0.72, 1.16]	0.95	[0.81, 1.11]	0.98	[0.87, 1.09]	0.90	[0.75, 1.08]
>12 years	0.67	[0.46, 0.98]*	0.88	[0.67, 1.15]	0.99	[0.83, 1.17]	0.97	[0.86, 1.09]	1.08	[0.88, 1.32]
Equivalised income (vs. 2–4 million JPY)										
< 2 million JPY	1.01	[0.78, 1.32]	1.05	[0.84, 1.30]	1.05	[0.92, 1.21]	1.04	[0.94, 1.15]	1.23	[1.04, 1.45]*
> 4 million JPY	0.94	[0.58, 1.51]	1.11	[0.77, 1.58]	0.98	[0.76, 1.25]	0.89	[0.74, 1.06]	1.17	[0.89, 1.54]
Smoking status (vs. never)										
Current	0.88	[0.50, 1.53]	1.27	[0.88, 1.83]	1.03	[0.80, 1.32]	1.08	[0.91, 1.29]	1.02	[0.72, 1.44]
Used to	1.32	[0.88, 1.99]	1.19	[0.88, 1.61]	1.24	[1.02, 1.51]*	1.24	[1.09, 1.42]**	1.12	[0.85, 1.46]
Drinking status (vs. never)										
Current	0.75	[0.54, 1.04]+	0.79	[0.62, 1.02]+	1.00	[0.85, 1.18]	1.11	[0.99, 1.24]+	0.88	[0.70, 1.09]
Used to	0.62	[0.25, 1.50]	0.82	[0.47, 1.43]	0.95	[0.67, 1.36]	0.93	[0.72, 1.20]	1.43	[0.95, 2.14]+
Observations	2477		2470		2482		2496		2485	

Exponentiated coefficients.
+p < .10, *p < .05, **p < .01, ***p < .001.

Discussion

This study investigated the associations of disaster damage and social support with persistent sleep problems among older survivors of the 2011 Great East Japan earthquake and tsunami. We hypothesized that each type of disaster damage and social support would predict each dimension of sleep problems, but the results painted a more complicated picture. Specifically, financial hardship predicted higher risks of short sleep duration, sleep insufficiency, poor sleep quality, and insomnia symptoms. Home destruction was associated with more sleep medication use. Health care disruption was linked to poor sleep quality. Unexpectedly, loss of close relatives or friends was not associated with any indicators of sleep problems. Social support in the form of instrumental support was linked to lower risks of all sleep problems whereas emotional support was tied to lower risk of poor sleep quality.

The material impacts of damage caused by the disaster (financial hardship, home destruction, and health care disruption) emerged as salient predictors of sustained sleep problems whereas there was no evidence that loss of close relatives or friends was associated with sleep problems over 2.5 years of follow-up. This might arise from the fact that our sample consisted of participants aged 65 years or older. It was likely that older survivors endured on-going struggles to rebuild their lives. For instance, survivors with financial hardships might be unable to afford tangible life essentials such as replacing an inundated mattress or buying quality food, which would affect their sleep. They might also have to deal with other sources of stress such as the hassles of getting insurance payments and government compensation. Most of the older adults were retired and their capacity to earn money (besides pension) might be limited, which might make them more vulnerable to financial hardship. Additionally, compared to those with no home destruction, people whose homes were partially or completely destroyed lived in a worse physical environment. The limited living space, the thin walls, together with the suboptimal thermal environment and sanitary conditions might contribute to sleep problems. Moreover, older adults might be more sensitive to health care disruption compared to younger generations if frailer and in greater need of health care. They might not have recovered from such damage after 2.5 years. On the other hand, loss of close relatives or friends might be a more normative experience as people age. Thus, older adults might become more resilient and might have recovered from loss of close relatives or friends over 2.5 years. The associations that we observed might be different had the follow-up been conducted closer to the trauma. For instance, significant relationships between loss of close relatives or friends and sleep problems might emerge if the follow-up was within a year of the disaster. The implication from our findings, that the material aspects of disaster damage, but not

loss of loved ones, had persistent impacts on older survivors' sleep over 2.5 years of follow-up is consistent with findings from previous research on disaster damage's impacts on depressive symptoms and cognitive decline among older survivors [31, 61].

Most prior studies focusing on sleep have treated disaster damage as a general experience but not differentiated between types of disaster damage. An exception in this regard is Matsumoto and colleagues' work [41, 42]. They conducted a cross-sectional survey on 4176 household members in the Ishinomaki area 6–12 months after the 2011 Great East Japan earthquake and tsunami. They found that lack of pleasure in life and lack of interaction with neighbors were associated with sleep difficulties, but none of the disaster exposure variables predicted sleep difficulties [41]. The same team of investigators reported similar results using cross-sectional data on 2593 respondents in the same area 1–2 years after the disaster [42]. There are at least three reasons why they did not find associations between disaster damage and sleep difficulties but we did. First, the different definitions of sleep outcomes made it difficult to directly compare the results. Specifically, Matsumoto and colleagues assessed sleep with just one question asking whether or not the participants had sleep difficulties. The question was answered by the representatives of households but not necessarily by the individuals who had actually experienced the symptoms, which might have induced more measurement error. In contrast, we incorporated five indicators of sleep problems that were reported by the individuals who experienced the symptoms themselves. Second, the study populations were different in that Matsumoto and colleagues assessed younger populations while our study examined older populations. Third, the follow-up times were different as Matsumoto and colleagues evaluated the question in shorter periods (6 months to 2 years) compared to that of our study (2.5 years).

Our findings also contribute to the broader stress and sleep/insomnia literature. For instance, financial strain (as a measure of chronic stress) has been associated with decreased sleep quality in older adults [62, 63]. Our result that financial hardship was associated with sleep onset insomnia (but not sleep maintenance insomnia) provides evidence along this line. Specifically, financial hardship might lead to chronic pre-sleep rumination. Prolonged worries about safety and food might induce cognitive arousal, which might delay sleep onset. Prior research on stress and sleep is usually limited by potential endogeneity problems in that unobserved confounders in observational studies could bias the results. If a person has an intrinsic characteristic for risk-taking or gambling, he/she would be more likely to have more financial strain and have worse sleep because of risk-taking behaviors. In comparison to most prior studies on stress and sleep, our study, a natural experiment, is much less likely to have the endogeneity problem as the instruments for stress (e.g. financial hardship) were imposed by a natural disaster and were thus exogenous.

With regards to social support, the results revealed a similar pattern as that of disaster damage: the tangible form—instrumental support—had protected the older adults from more adverse sleep indicators than emotional support did. This might be true because older people generally had worse physical health compared to younger age groups and had more needs for people to take care of them while sick. Our findings are in line with previous research showing that social support protects people from sleep problems [38–40, 42]. We made a contribution by using pre-disaster social support information that removed recall bias and distinguished between forms of social support and by showing that instrumental support was more relevant to sleep outcomes than emotional support among older disaster survivors.

We also tested for interaction effects between disaster damage and social support variables on sleep indicators. There was no evidence of an interaction between disaster damage and social support, suggesting that they had independent effects on older survivors' sleep.

Strengths, Limitations, and Future Directions

This study features three strengths. First, it took advantage of a unique prospective design that strengthened causal inference by providing pre-disaster information that established temporality and protected inference from recall bias, and by providing an appropriate control group such that comparisons were made between residents living in the same municipality who happened to be in locations that tsunami did or did not reach.

Second, this study incorporated several indicators on the outcome of interest (sleep) and the predictors of interest (disaster damage and social support). This allows us to identify which dimensions of sleep are sensitive to which aspects of disaster damage and social support. The differential and interesting associations of disaster damage and social support call for more research on this topic to elucidate the mechanisms.

Third, the focus on older adults followed for an extended period (2.5 years) helped us to understand the long-term struggles of those in greatest needs. Older adults are disproportionally affected both during and after disasters, because of chronic diseases or conditions, impaired physiological and cognitive changes experienced as part of aging, as well as social and economic limitations that prevent adequate preparation before disasters and impede recovery after disasters [36, 37]. For these reasons, CDC urges that the frail older adults are recognized as a special-needs population in emergency management and strategies should be developed to meet their needs [64].

The first limitation of the study was that sleep, disaster damage, and social support, were all self-reported, which might induce common-method bias. When the same respondent provides information on measures of both the predictor and the outcome, artifactual covariance between the two variables might arise [65]. For instance, distress induced by exposure to disaster might lead participants to amplify the extent to which their financial situations or health care access deteriorated after the disaster and to amplify the severity of their sleep problems, which might induce spurious relationships between the exposures and the outcomes. Home destruction and loss of close relatives or friends should be less prone to such bias as they were defined more operationally. Also, while the self-reported sleep indicators capture different dimensions of sleep health, they have not been validated to the same extent as the PSQI scale. Future research could consider using objective measures of sleep such as actigraphy data.

In addition, the main analyses did not control for pre-disaster sleep. Only a quarter of the sample was asked the sleep questions at baseline, and so we did not have adequate power to evaluate how sleep changed over time in relation to disaster damage and social support. Moreover, one might also be concerned about selection bias as the pre-disaster sleep

questions were administered based on Iwanuma's school districts such that respondents who were asked the pre-disaster sleep questions (in districts of South Iwanuma, Iwanuma, and West Iwanuma) lived further away from the coastline compared to those who were not asked the questions (in district of Tamaura). In this case, controlling for pre-disaster sleep might introduce selection bias as those who were most severely hit by the disaster would be excluded. We, therefore, chose to focus our research question on predictors of persistent post-disaster sleep problems among older disaster survivors. In exploratory analyses, we looked at sleep changes from pre- to post-disaster in the subsample where pre-disaster sleep assessment was available. The crude prevalence decreased slightly for most sleep problems (short sleep duration: 8.7% to 6.3%; sleep insufficiency: 14.7% to 11.2%; poor sleep quality: 28.0% to 24.8%; insomnia symptoms: 42.0% to 39.0%; sleep medication use: 16.7% to 17.7%). Result from regression models controlling for pre-disaster sleep showed that the majority of the effects remained in the same directions yet were attenuated (e.g. effect of financial hardship on short sleep duration: RR decreased from 1.40 to 1.12; effect of financial hardship on insomnia symptoms: RR decreased from 1.13 to 1.06). Most effects were no longer statistically significant. This was expected due to the sharp decrease in sample size. In this subsample, we also explored interaction effects between indicators of pre-disaster sleep and disaster damage. There was no evidence that poor pre-disaster sleepers were more vulnerable to sleep problems after exposure to disaster. It would be of interest for future studies to take pre-disaster sleep into consideration.

Selection bias was a potential problem due to the 59.0% baseline response rate and the 82.1% follow-up response rate. However, it was shown in prior research that the Iwanuma cohort at baseline was representative of the whole older adult population in Iwanuma city in terms of demographic characteristics [30]. Thanks to the cooperation of the Iwanuma city administration using the official residential registry, only 17 respondents could not be tracked at follow-up. Five-hundred sixty other respondents were successfully tracked but lost to follow-up due to sickness, death, or relocation. Out of 4380 participants eligible for the follow-up survey, 786 did not respond. We found that people who responded to the follow-up survey did not differ significantly from those who did not respond, especially in terms of disaster damage. While we did not have disaster damage information from people who did not respond to the follow-up survey, residential distance from coastline information was collected at baseline, which could serve as a proxy for disaster damage. The distributions of distance from coastline among people who responded and who did not respond were very similar (Supplementary Table S2).

Future research could evaluate if exposure to disaster damage modifies the associations between health disruption and sleep disturbances. It is possible that experiences of disaster might amplify health disruption's effects on sleep as people in poorer health might be more vulnerable to the physical and psychological impacts caused by the trauma, which could impair their sleep.

Lastly, while our findings contribute to knowledge on persistent sleep problems among older survivors, future research is warranted to assess if the findings are generalizable to populations in other age groups and/or from other countries.

Conclusions

We have demonstrated that different types of disaster damage and social support were associated with older survivors' persistent sleep problems in many but very different ways. The findings could shed light on targeted interventions to mitigate lingering sleep problems and the associated adverse health outcomes among older disaster survivors. For instance, in addition to grief counseling, long-term reconstruction efforts for older survivors could be directed to the provision of material support such as financial assistance, home repair and shelter assistance, and continued access to health care, in order to promote recovery after the disaster. Efforts could also be directed to the promotion of instrumental support to protect older adults. These efforts would contribute to higher resilience, better disaster preparedness, and faster recovery among disaster-affected communities.

Supplementary material

Supplementary material is available at *SLEEP* online.

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Notes

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