Abstract

Natural disasters have long-lasting negative consequences to the physical and psychological health of the survivors. Guided by the Disablement Process framework, this study examined how the exposure to the Great East Japan earthquake and tsunami of 2011 was related to the prevalence and incidence of disability among older men and women in Japan. Data came from two waves (2009 and 2013) of the Nihon University Japanese Longitudinal Study of Aging (NUJLSOA). We used logistic regression to model how the disaster experience was associated with the prevalence of disability in 2013 and the incidence of disability between 2009 and 2013. We documented a significant relationship between the disaster and disability. Older adults who were affected by the event exhibited significantly greater odds of reporting disability in 2013, and developing disability between 2009 and 2013. Further, the findings indicate that older individuals who experienced damage to their health, property, and were forced to changes their lifestyles due to the disaster were at increased risk of reporting disability in 2013 and being disabled between 2009 and 2013. The Disablement Process posits that disability is "a gap between personal capability and environmental demand." Current results suggest that natural disasters, including earthquakes and tsunami, can destroy social infrastructure and disrupt people's daily lives, thereby widening the gap between environment and personal resources. Given the increasing number of natural disasters in the world, more policy attention needs to be directed toward reducing disaster-related adverse physical health consequences particularly among older people. (245 words)

1. Background

The 9.0-magnitude earthquake struck off the north-eastern coast of Japan on 11 March 2011. It was followed by a massive tsunami, resulting in more than 19 thousands deaths, 2,500 people missing, 6,000 people injured, and about 6,200 people displaced (Fire and Disaster Management Agency, 2018). Although it has been 8 years since the Great East Japan earthquake and tsunami, the catastrophic event continues to take a serious toll on Japanese people, particularly older adults. According to the Reconstruction Agency (2018a), for instance, approximately 90% of disaster-related mortality, denoting deaths from worsening conditions caused by the 2011 earthquake and tsunami, are concentrated among those older than 65 years. These observations indicate that natural disasters can have long-lasting deleterious impacts on the health of individuals, and older people are particularly susceptible to disaster-related shocks.

In this paper, we investigate the physical health consequences of the Great East Japan earthquake and tsunami of 2011 among older men and women. Our measurement of physical health is disability, defined by difficulty in activities of daily living (ADLs). Previous studies about the 2011 disaster have explored the consequences of disasters on psychological health, as assessed by levels of psychological distress (Goodwin et al., 2015; Niitsu et al., 2014; Sugimoto et al., 2015; Yokoyama et al., 2014) or depressive symptoms (Inoue et al., 2014; Kukihara et al., 2015; Sasaki et al., 2018; Tsuboya et al., 2016). Among studies assessing physical health, most have focused on mortality during and after the event (Aida et al., 2017; Aldrich & Sawada, 2015; Morita et al., 2017). Disability is unique, as it reflects the interplay between individuals and their environment (Verbrugge & Jette, 1994). Natural disasters can increase the risk of disability by

drastically changing the circumstances in which individuals are embedded. Accordingly, we adopt a Disablement Process perspective as a theoretical framework for understanding the physical health consequences of the Great East Japan earthquake and tsunami of 2011 among Japanese elders.

The current study makes three sets of contributions to the existing literature. First, we draw on two waves of the Nihon University Japanese Longitudinal Study of Aging (NUJLSOA) data to estimate the prevalence (in 2013) and incidence of disability (between 2009 and 2013). Many studies to date have relied on health information collected in the aftermaths of disasters. The absence of pre-disaster information makes it difficult to separate the effects of disasters from those of preexisting health problems, which are likely to influence post-disaster health status (Seplaki et al., 2006). The present study overcomes this limitation by using data collected before and after the Great East Japan earthquake and tsunami. Second, we use nationally representative data to model links between the disaster and disability among Japanese elders. Prior research on the 2011 event is typically based on samples from small cities (Aida et al., 2017; Morita et al., 2017; Niitsu et al., 2014; Sasaki et al., 2018; Yokoyama et al., 2014). The current study relies on representative samples of the national-level older adult population of Japan, thereby increasing the generalizability of the findings. Third, the present analysis includes a variety of individual-level factors related to disaster-exposure as well as disability. It is possible that the effect of disasters would be weakened when controls for background variables are entered. Statistical adjustments for a number of confounding factors allow us to assess the strength of the impacts of disasters on physical health status.

1.1 Natural Disasters and Older People's Health

A large volume of disaster research shows that older people are more likely to physically and psychologically suffer from natural disasters compared to their younger counterparts (Cherniack, 2008). Several explanations have been put forward. First, physical health status deteriorates with advancing age. Older age is associated with a higher chance of being disabled (Freedman et al., 2008), suffering from visual and hearing impairments (Gu et al., 2013), and being bedridden (Klenk et al., 2015). Physical health problems reduce mobility and make it difficult to quickly respond to disasters. Also, cognitive skills decline with age. Elderly individuals lose orientation to time and space, language comprehension, concentration, and attention (Mirowsky & Ross, 2003). Decreased mental functions prevent elders from collecting, analyzing, and processing information, making informed decisions, and seeking help in the wake of disasters.

Past research findings from all over the world confirm older individuals' vulnerability to disaster-related shocks. According to Brunkard and colleagues (2008), for instance, the average age of Hurricane Katrina's victims in four areas in Louisiana was 69.0 years, and about half of the fatalities was above 75 years of age. Similar age-based mortality differences were noted in Klinenberg's (2003) work on the Chicago heat wave in 1995. The victims of the heat wave were disproportionately old; about 73% of them were older than 65 years. Importantly, senior citizens who were living alone were at elevated risk of dying from the heat, indicating the danger of social isolation at advanced ages. Similar findings come from research on the 1999 Chi-Chi earthquake in Taiwan (Liang et al. 2001), the 2004 Indian Ocean tsunami (Doocy, 2007; Rofi, Doocy, & Robinson, 2006), the 2009 earthquake in central Italy (Alexander & Magni, 2013), and

the 2010 earthquake in Chile (Labra, Maltais, & Tremblay, 2016). Older people were indeed overrepresented in the death tolls from the Great East Japan earthquake and tsunami of 2011. In Iwate, Miyagi, and Fukushima Prefectures where 99% of the victims resided, 10,409 people, or 66.1% of the fatalities, were older than 60 years of age (Cabinet Office of Japan, 2017).

Elderly individuals are not only likely to die during disasters, but also to suffer the adverse physical and psychological health consequences in the aftermath of disasters. Labra and colleagues (2018) conducted in-person interviews with older Chilean men and women four years after the 2010 earthquake. Most respondents experienced post-traumatic psychological problems, including fear, anxiety, panic, and depression. Importantly, their physical health status gradually deteriorated over the four-year follow-up period, as manifested by increases in muscle pains, hypertension, and fatigue. Evidence from Japan also confirms that natural disasters impose substantial burdens on the health of older survivors. A qualitative study by Kato et al. (1996) found that older individuals suffered from sleep disorders, hypertension, depression, and irritability after the Hanshin-Awaji earthquake in 1995. Importantly, the impacts of a disaster may differ by the level of individual exposure. Direct exposure, denoting damages directly caused by a disaster to individuals, produces particularly negative consequence to health. For instance, Isatanuwatchai et al. (2017) reported that direct exposure to the 2004 Indian Ocean tsunami (e.g., personal injury, a loss of a family member, and a loss of business) had negative impacts of the mental health status of the survivors, while the variables of indirect exposure (e.g., a loss of a family member's business and injury to a family member) were only weakly related to mental health conditions. Spalki et al. (2006) found

that damage to property was a key predictor of depressive symptoms among older victims of the 1999 Chi-Chi earthquake in Taiwan. These previous research findings suggest that the levels of individual exposure to a disaster hold the key to better understanding the relationship between disability and disaster experiences.

1.2 Natural Disasters in the Context of the Disablement Process

Verbrugge and Jette (1994) proposed a socio-medical framework of disability, known as the Disablement Process. What distinguishes this model from previous work is the emphasis on the interplay between personal and environmental factors. Disease or injuries (pathology) first lead to impairments and then cause functional limitations. It is important to note that functional limitations do not always result in disability: functional limitations occur when there is "a gap between personal capability and environmental demand (p.1)." Thus, modifying external circumstances to meet one's physical and mental needs and capacity would prevent disability.

The Disablement Process helps us understand the physical health consequences of natural disasters for two key reasons. First, disasters deteriorate "extra-individual" factors by destroying the built environment. An earthquake may cause road closures, making it difficult for a patient with diabetes to go to a clinic to have an oxygen tank refilled. A failure to receive the oxygen therapy may lead to visual impairment and result in difficulty in performing daily activities, such as going to school or work. In this case, the earthquake produces an imbalance between one's demands (the need to fill an oxygen tank) and the environment (transportation to a clinic), thereby resulting in disability (having difficulty in performing social role activities). Second, disasters damage personal

resources, or “intra-individual factors.” Many people are forced out of their homes and displaced in the aftermath of disasters, and involuntary relocation may result in a loss of contacts with family, friends, and communities. Further, disasters erode social and economic functioning of communities, and negatively influence the psychological well-being of the many. Research on the 2004 Indian Ocean tsunami shows that community destruction was related to increased traumatic stress disorders, net of personal experiences (Frankenberg, Nobles, & Sumantri, 2012). Social isolation is particularly harmful for older people’s well-being, as it negatively influences their coping skills and lowers their sense of mastery or self-esteem (Mirowsky & Ross, 2003).

Evidence suggests that the Great East Japan earthquake and tsunami of 2011 devastated social and personal resources for people in the north-eastern part of the country. The massive tsunami destroyed a total of 20 stretches of expressways (870km, about 540 miles) along the Pacific coast (Kazama & Noda, 2012). Railway facilities were severely damaged, and so were electricity, gas, and water infrastructure. Many buildings were fallen, with approximately 400,000 houses completely or partially collapsing (Fire and Disaster Management Agency, 2018). A large number of residents in the devastated areas were forced out of their home towns. In total, about 60,000 people are still evacuated, and 67% of them still reside in shelters or temporary homes (Reconstruction Agency, 2018b). Interviews with individuals who left their homes after the meltdown at the Fukushima Daiichi nuclear power plant demonstrate how subsequent to the disaster people suffered from fragmented social networks, characterized by the combined loss of trust, community ties, and interpersonal relationships, and feelings of helplessness (Eguchi, 2015). Taken together, evidence reviewed to this point indicates that the 2011

disaster may have increased disability by drastically altering the environment in which people lived and destroying social and personal resources.

Guided by a Disablement Process perspective, the present study examines the following three research questions:

Question 1. Is the exposure to the Great East Japan earthquake and tsunami related to the prevalence of disability among older people? Given the capability of a disaster to widen the gap between environment and personal resources, we expect that disaster experiences in 2011 would be related to higher odds of reporting disability in 2013.

Question 2. Is the exposure to the disaster associated with the onset of disability? We predict that, among those without disability, the exposure to the disaster would increase the risk of developing disability between 2009 and 2013.

Question 3. Do the impacts of the 2011 disaster vary by the levels of individual exposure? We anticipate that those who were directly affected by the event would be at greater risk of having disability compared to those who were not.

2. Data and methods

2.1 Data

The NUJLSOA is a nationally representative sample of Japanese men and women older than 65 years of age at the time of the initial data collection in 1999. The aim of the survey is to investigate the factors producing changes in the physical and mental health status of Japanese elders. The survey includes a variety of information about older people's physical and mental health, socioeconomic status (SES), living arrangements, and inter-personal relationships. The NUJLSOA has a panel design with baseline data

collected in 1999 (n=4,997) and follow-up surveys conducted in 2001 (n=4,950), 2003 (n=4,888), 2006 (n=3,879), 2009 (n=2,886), and 2013 (n= 1,444). Longitudinal analyses face the problem of data loss due to death or attrition. In total 1,444 men and women participated in the 2013 survey, changing from 2,886 individuals in the 2009 survey. This is largely due to the fact that the 2003 survey was based on mail, while the first 5 waves of 2001, 2003, 2006, and 2009 were based on face-to-face interviews. Since the questions about natural disasters were included only in the 2013 wave, the current study uses two waves (2009 and 2013) of the NUJLSOA data. The survey was conducted throughout Japan using multistage sampling methods. It only included community living residents and oversampled those aged 75 and older. Younger respondents were added in 2001 and 2003. More details about the NUJLSOA survey have been published elsewhere (http://grantome.com/grant/NIH/R03-AG021609-02).

2.2 Measurements

Disability. Our dependent variable is disability, defined by difficulty in activities of daily living (ADLs). Respondents who reported difficulty in doing the following items were considered to have an ADL limitation: (1) bathing, (2) dressing, (3) feeding, (4) moving from bed, (5) mobility around the home, (6) toileting, and (7) going out. The information was then converted into a binary variable with those who reported having at least one ADL difficulty coded as 1 (disabled) and otherwise as 0.

Disaster experiences. The major independent variable is the exposure to the Great East Japan earthquake and tsunami. The 2013 wave of the NUJLSOA contains a set of questions about the experiences of the disaster, including the Fukushima Daiichi nuclear power plant accident. Respondents were asked whether (1) their health was affected; (2)

they experienced damage to their houses or properties; (3) they were forced to change their lifestyles; and (4) their relatives or friends were affected. Response options included "absolutely yes," "somewhat yes," "somewhat no," and "absolutely no." We created three dichotomous variables: (1) exposure to the 2011 disaster (1=those who answered "yes" or "somewhat yes" to any of the four disaster-related questions); (2) direct exposure (1=those who answered "yes" or "somewhat yes" to the questions about health, damage to property, and forced changes in lifestyles); and (3) indirect exposure (1=those who answered "yes" or "somewhat yes" to the question of their relatives or friends being affected).

Background characteristics. We included a set of socio-demographic variables to account for the effects of confounding factors. *Gender* is a dummy variable with females 1 and males 0. Compared to men, women are more likely to report disability (Crimmins, Kim, & Sole-Auro, 2011) and are at higher risk of suffering from natural disasters (Rofi et al., 2006). We include *age* in years. We also ran models with 10-year age intervals (70-79, 80-89, and 90+), but the relationships between age and disability remained unchanged. Our models included several risk factors for physical health problems. *Low education* refers to those without a high school diploma. In contrast to other adulthood socioeconomic indicators, such as occupation, employment, and income, educational attainment is relevant to a larger segment of the population. This point is particularly important, because our sample consists of older individuals who are likely to be retired or out of the labor force. Further, low education is a powerful predictor of increased morbidity as well as mortality, as it narrows the access to health-enhancing resources (Link & Phelan, 1995). In addition to lower educational attainment, we focused on

financial conditions as a measurement of SES. *Economic hardship* was constructed from a question asking: "Do you have enough financial resources for your family?" Response categories included "more than enough," "enough," "occasionally not enough," and "not at all enough." We created a dichotomous variable of 1 for those experiencing economic hardship (defined as "occasionally not enough," and "not at all enough") and 0 otherwise. We added a measurement for *social isolation*, referring to respondents who lived alone (=1) at the time of the data collection. We paid special attention to living arrangements, because elderly individuals living alone are particularly vulnerable to natural disasters (Klinenberg, 2002).

Self-rated health and *chronic conditions* were included as measures of physical health status. Self-rated health is the respondent's subjective assessment of their health condition, and it is closely related to disability among older people (Galenkamp et al. 2011). We created three categories of self-rated health: good ("absolutely healthy" and "healthy" combined, referent), fair ("fair"), and bad ("unhealthy" and "absolutely unhealthy" combined). Also, we included the number of chronic conditions reported by respondents, considering that chronic illnesses are major risk factors of disability at advanced ages (Martin & Schoeni, 2014).

2.3 Analytical Design

There are two types of models. In the prevalence model, we used logistic regression to assess the relationship between the experience of the 2011 disaster and disability experiences in 2013. We first estimated a reduced model which only included exposure to the disaster (model 1). We then added a set of background characteristics to

determine to what extent the inclusion of confounding factors may alter the observed relationships between the disaster and disability (model 2). Control variables in the prevalence model were taken from the 2013 wave. The measurement of disability in 2009 was included in models 1 and 2 to account for pre-disaster disability status. The incidence model focused on the onset of disability between 2009 and 2013. The sample was restricted to those who did not report any ADLs in 2009. We used logistic regression to model how the exposure to the 2011 disaster was associated with the onset of disability between 2009 and 2013 among those without any ADLs prior to the disaster. Controls in the incidence model were from the 2009 wave. Also, we tested the influence of the confounding factors by employing reduced (model 1) and full (model 2) form models.

Those with missing values on disaster-related questions were dropped from the analyses. Other variables with missing data were imputed by assigning the mean (for continuous variables) or modal response (for categorical variables) of the non-missing items. We also ran models where those with missing values on any variables included in the analysis were excluded. Given that (1) we found no difference between the imputed and non-imputed results; (2) and a larger sample size yields stronger power to support the significance tests, we reported the findings based on the imputed data. The final sample size for the incident model was 1,112 for the prevalence model and 984 for the onset model. Analyses throughout used the NUJLSOA sample weights and were conducted in Stata 13.0 (StataCorp, 2013).

3. Results

Table 1 presents sample characteristics of men and women from the NUJLSOA 2013 survey. Approximately 36% of the sample reported having difficulty in activities of daily living (ADLs) in 2013. Among those who were without any ADLs in 2009, about 29% of them developed disability by 2013. Overall, 17% of respondents were affected by the Great East Japan earthquake and tsunami of 2011. 11% experienced direct exposure (e.g., they experienced impacts on their health, house, and property, and forced changes in lifestyles), whereas 12% of respondents reported indirect exposure (e.g., their relatives or friends were affected). The sample included 55% women and 45% men. The mean age of the sample was quite high, 82.34 years old. This is due to the fact that the first wave of the survey was conducted in 1999, and those aged 65 and older were included in the sample frame. About 70% of the sample was without a high school diploma, suggesting lower levels of educational attainment among Japanese elders. About 37% did not have enough financial resources for their family, and 13% lived by themselves. The modal self-rated health status was "fair" (49.51%), followed by "bad" (32.83%) and "good" (17.66%). The average number of chronic conditions in this sample was 1.73.

Multivariate models: 2011 Disaster and Disability among Older Adults

Table 2 summarizes the results of the prevalence model. The focal independent variable is any type of experience of the 2011 disaster. It is clear from model 1 that the experiences of the Great East Japan earthquake and tsunami are strongly associated with the prevalence of disability in 2013. Older men and women who were affected by the 2011 disaster exhibited 61% greater odds of being disabled in 2013, net of pre-existing disability in 2009. In model 2, we added a set of background factors. Results in model 2 demonstrate that the relationship between the 2011 disaster and disability remained

almost unchanged even when sociodemographic indicators, living arrangements, and existing health conditions were accounted for. Older adults affected by the 2011 disaster displayed 54% higher odds of reporting disability in 2013 than those who were not, net of all controls.

Model 2 reveals several factors related to disability among Japanese elders. Women have 66% higher odds of reporting disability compared to men. We also included an interaction term between the disaster and gender, but found no significant gender differences in the effect of the disaster on disability. Older age is strongly related to disability. None of the SES and social isolation variables was associated with disability experiences. Having low education, not having enough financial resources for a family, and living alone were associated with greater odds of reporting disability, but not significantly so. In contrast, physical health conditions are important for disability among Japanese elders. Having fair or bad self-rated health was related to significantly greater odds of being disabled. Those with bad self-rated health had more than 7 times higher odds of being disabled compared to those with good self-rated health. Also, a one-unit increase in the number of chronic conditions was associated with 36% greater odds of reporting disability. In both models 1 and 2, disability in 2009 was associated with significantly higher odds of being disabled in 2013.

Next, we examined how the experiences of the Great East Japan earthquake and tsunami were associated with the odds of developing disability between 2009 and 2013 (Table 3). Results in Model l show that being affected by the Great East Japan earthquake and tsunami was associated with higher odds of the onset of disability during the follow-up period. If adults without any difficulties in ADLs in 2009 were affected by the disaster

in 2011, they reported 64% greater odds of being disabled in 2013 compared to those who were unaffected. Model 2 adds a variety of sociodemographic and health variables. Results show that the statistical adjustments for confounding factors in model 2 produced no appreciable changes in the measured association between the disaster and the incidence of disability. Those who were affected by the disaster in 2011 had 54% greater odds of developing disability during the follow-up period, net of all controls. In the incidence model, being an older woman, having worse self-rated health, and suffering from a larger number of chronic illnesses were significantly associated with the onset of disability among Japanese elders.

Finally, we investigate the extent to which the impacts of the 2011 disaster differ by the levels of exposure. It is clear from Table 4 that only direct exposure to the event is significantly related to the odds of having disability in 2013. Older men and women who said that their health, house, or properties were affected, or they were forced to change their lifestyles due to the 2011 disaster exhibited 76% greater odds of having disability in 2013, net of all controls. Indirect exposure (e.g., one's relatives or friends were affected by the disaster) is only weakly associated with disability. Further, consistent with the prevalence model, direct exposure to the disaster is strongly related to higher odds of developing new disability between 2009 and 2011. Those who experienced direct damages due to the disaster had 68% greater odds of reporting disability between 2009 and 2013, and the results remain significance net of all controls. Indirect exposure is not strongly associated with the onset of disability during the study period. These results suggest that the consequences of the disaster are largely dependent on the levels of

exposure, and direct exposure to the event appears to have strong negative impacts on physical health status of older adults in Japan.

[Tables 1, 2, 3 and 4, about here]

4. Discussion

8 years have passed since the Great East Japan earthquake and tsunami, but the scars of the event still remain visible in Japanese society. Guided by the Disablement Process model, the present study investigated how the experiences of the catastrophic event of 2011 were related to the prevalence and incidence of disability among Japanese elders. Three main findings of the analyses are worth noting. First, we documented a significant relationship between the 2011 disaster and the prevalence of disability. Those who were affected by the disaster exhibited higher odds of being disabled in 2013, net of sociodemographic characteristics, living arrangements, and disability prior to the disaster. Second, the exposure to the disaster was associated with the onset of disability. Among people without any ADLs limitations, those who were affected by the 2011 earthquake and tsunami had greater odds of developing disability between 2009 and 2013. Again, the observed relationship remained significant after adjustment for background characteristics. Third, this study showed that direct exposure to the 2011 disaster had particularly negative impacts on the physical health status of Japanese elders. If people experienced damages to their health, house, properties, or lifestyles, they had higher odds of experiencing disability in 2013 or developing disability between 2009 and 2013. Taken together, these results suggest that the Great East Japan earthquake and tsunami of 2011 had detrimental consequences for the physical health status of older people, as measured

by the prevalence and onset of disability, and direct exposure to the event had particularly strong negative health consequences.

The Disablement Process posits that the availability of "intra-personal" and "extra-personal" resources holds the key to disability. We focused on a natural disaster as a factor that can drastically alter both social and personal environments. Destruction of the infrastructure may raise hurdles for people with functional limitations to perform daily activities. Moreover, disasters result in community demise. According to the Disablement Process model, personal resources contribute to reducing environmental demands, as individuals receive emotional and instrumental support from interpersonal connections. Natural disasters, however, damage the functions of communities and erode social connections through forced relocation and evacuation (Frankenberg et al., 2012). These observations help us understand documented associations between the 2011 disaster and disability. The massive earthquake and tsunami destroyed social infrastructure and caused drastic changes to the lives of a large number of older people. Evacuation and relocation forced many of them to be separated from daily routines and deprived them of connections with family and friends. Thus, the 2011 earthquake and tsunami destroyed both environmental and personal resources, leading to the widening of the gap between the environment and individual factors, that is, disability.

Our study has two important implications for policy. First, continued efforts toward reconstruction of devastated areas are important. Major infrastructures, including roads and railways, are almost restored, but more attention needs to be directed to improving living conditions of older people. Hardships faced by older citizens in devastated areas could be alleviated somewhat with financial assistance for renovating

damaged houses, the establishment of shuttle bus services to transport older people to and from medical facilities. These types of services are particularly important for senior individuals living alone. Second, it is important to help older people stay socially active following disasters. Being embedded in social networks provides older people with various types of support and enriches personal resources (Musick, Regula Herzog, & House, 1999). In the aftermath of natural disasters, visits by volunteers or telephone check-in programs ensure the safety of older people, offer a sense of comfort and relief, and provide instrumental support, such as the information of emergency food supplies or the location of shelters.

The contribution of this research rests on the use of nationally representative data, the inclusion of health information collected before and after the disaster, and the adjustment for various sociodemographic factors. Our analyses are not without limitations, however. First, the present study focuses only on ADLs to define disability. This is primarily because this research concerns the physical health consequences of the 2011 catastrophe. The NUJLSOA includes questions about difficulties in instrumental activities of daily living (IADLs). We conducted supplemental analyses using ADLs and IADLs combined and IADLs alone as our outcome variables, but found no significant associations with the exposure to the disaster. To further investigate the health effects of the 2011 disaster, we used other indicators, including mortality, self-rated health, functional limitations, sleep disorders, and depression. None of these indicators was significantly associated with the experience of the 2011 disaster. These results raise the possibility that the Great East Japan earthquake and tsunami had particularly strong impacts on a severe type of disability, as measured by ADLs. Yet, it is important to ask

why other health indicators were not associated with the 2011 disaster. Future research could advance our findings by exploring precise mechanisms linking natural disasters to disability experiences.

Second, it is important to note that our sample size is small. The present study utilized data from the last two waves of the NUJLSOA (2009 and 2013), since disaster-related questions were included only in the 2013 survey. In 2013, the sample size was down to 1,444 from 2,886 in 2009, as a result of a change in data collection mode. The first 5 waves of the NUJLSOA were based on face-to-face interviews, whereas the 2013 survey was conducted via regular mail. A mail survey is faced with a challenge of lower levels of overall response rates compared to other types of data collection, namely in-person interviews. The sample size was further reduced, as we excluded those with missing data on disaster-related questions. Our rationale for this decision is that missing information cannot be reasonably imputed for personal experiences of the disaster. In attempts to keep the sample size as large as possible, we used the imputation strategy for other variables and found that, with or without imputation, the results remained unchanged. The issue of a small sample size may explain why we failed to detect a strong relationship between disability and other types of health indicators, or a lack of strong impacts of sociodemographic factors on disability. Overall, it is important to bear in mind that, although this study is based on nationally representative data, the sample size remains small, suggesting that the generalizability of the findings may be reduced.

Third, there is a two-year time lag between the disaster (2011) and data collection (2013). While adverse effects of traumatic experiences on mental well-being tend to evolve over time (Pearlin et al. 2005), individuals may recover physical strength

relatively quickly after a disaster. Previous research has shown that physical health symptoms peak during the period immediately after a natural disaster and then decline linearly with time (Suzuki et al., 1997). This issue may be relevant to our findings that disability alone was associated with the 2011 disaster. Impacts on other types of physical health problems, such as self-rated health, functional limitations, and sleep disorders, may have evaporated during the two-year follow-up period. Natural disasters may cause a wide array of health problems, but long-term physiological wear and tear may only be visible in the form of disability. In addition, the present analysis ignores changes in health between 2009 and 2011. Although we controlled for the presence of ADLs in 2009 in statistical models, there is the possibility that respondents developed new disabilities or recovered from disability between 2009 and 2011. Readers should consider the issue of time lag when interpreting the results.

Recently, the number of natural disasters has been increasing globally. These include massive typhoons, heavy rain, flooding, and extraordinary heat and snow, on top of earthquakes. Considering recent increases in disasters striking Japan and its growing share of the elderly population in the overall population, the number of potential victims of natural disasters in Japan may be relatively large. The country is currently faced with the considerable challenge of how to minimize disaster-related human costs, particularly among older people. Japan's experiences therefore will offer valuable lessons for other countries, as natural disasters continue to be one of the major global threats.

References

Aida, J., Hikichi, H., Matsuyama, Y., Sato, Y., Tsuboya, T., Tabuchi, T., . . . Kawachi, I. (2017). Risk of mortality during and after the 2011 Great East Japan Earthquake and Tsunami among older coastal residents. *Scientific Reports, 7*(1), 16591. doi:10.1038/s41598-017-16636-3

Aldrich, D. P., & Sawada, Y. (2015). The physical and social determinants of mortality in the 3.11 tsunami. *Soc Sci Med, 124*, 66-75. doi:10.1016/j.socscimed.2014.11.025

Alexander, D., & Magni, M. (2013). Mortality in the L'Aquila (Central Italy) Earthquake of 6 April 2009. *PLoS Currents, 5*, e50585b50588e50586efd50581. doi:10.1371/50585b8e6efd1

Brunkard, J., Namulanda, G., & Ratard, R. (2008). Hurricane Katrina deaths, Louisiana, 2005. *Disaster Med Public Health Prep, 2*(4), 215-223. doi:10.1097/DMP.0b013e31818aaf55

Cabinet Office of Japan. (2017). Korei Shakai Hakusho (White paper on aging society). Retrieved from http://www8.cao.go.jp/kourei/whitepaper/w-2017/html/zenbun/index.html.

Cherniack, E. P. (2008). The impact of natural disasters on the elderly. *Am J Disaster Med, 3*(3), 133-139.

Crimmins, E. M., Kim, J. K., & Sole-Auro, A. (2011). Gender differences in health: results from SHARE, ELSA and HRS. *Eur J Public Health, 21*(1), 81-91. doi:10.1093/eurpub/ckq022

Doocy, S., Gorokhovich, Y., Burnham, G., Balk, D., & Robinson, C. (2007). Tsunami Mortality Estimates and Vulnerability Mapping in Aceh, Indonesia. *Am J Public*

Health, 97(Suppl 1), S146-S151. doi:10.2105/AJPH.2006.095240

Eguchi, T. (2015). “Hinanshiji Kuiki.” Pp. 62-83 in *Genpatsu Hinan Hakusho*, edited by Kanseigakuin Daigaku Saigaifukko Seido Kenkyujo, Hhgashinihondaisinsai Shien Zenkoku Network (JCN), and Fukushima no Kodomotachi wo Mamoru Horitsuka Network (SAFLAN). Kyoto: Jinbun Shoin.

Fire and Disaster Management Agency. 2018. Tohoku Chiho Taiheiyooki Jishin (Higashinihon Daishinsai) Torimatomeho (Reports on Great East Japan earthquake and tsunami). Retrieved from http://www.fdma.go.jp/bn/higaihou.html.

Frankenberg, E., Nobles, J., & Sumantri, C. (2012). Community destruction and traumatic stress in post-tsunami Indonesia. *J Health Soc Behav, 53*(4), 498-514. doi:10.1177/0022146512456207

Freedman, V. A., Martin, L. G., Schoeni, R. F., & Cornman, J. C. (2008). Declines in late-life disability: the role of early- and mid-life factors. *Soc Sci Med, 66*(7), 1588-1602. doi:10.1016/j.socscimed.2007.11.037

Galenkamp, H., Braam, A. W., Huisman, M., & Deeg, D. J. (2011). Somatic multimorbidity and self-rated health in the older population. *J Gerontol B Psychol Sci Soc Sci, 66*(3), 380-386. doi:10.1093/geronb/gbr032

Goodwin, R., Takahashi, M., Sun, S., & Ben-Ezra, M. (2015). Psychological distress among tsunami refugees from the Great East Japan earthquake. *BJPsych open, 1*(1), 92-97. doi:10.1192/bjpo.bp.115.000422

Gu, D., Zhou, J., Yong, V., Sautter, J., & Saito, Y. (2013). Age Differential Effects of Severity of Visual Impairment on Mortality among Older Adults in China.

Journal of applied gerontology : the official journal of the Southern Gerontological Society, 32(7), 876-888. doi:10.1177/0733464812438634

Inoue, M., Matsumoto, S., Yamaoka, K., & Muto, S. (2014). Risk of social isolation among Great East Japan Earthquake survivors living in tsunami-affected Ishinomaki, Japan. *Disaster Med Public Health Prep, 8*(4), 333-340. doi:10.1017/dmp.2014.59

Isaranuwatchai, W., Coyte, P. C., McKenzie, K., & Noh, S. (2017). The 2004 tsunami and mental health in Thailand: a longitudinal analysis of one-and two-year post-disaster data. *Disasters, 41*(1), 150-170. doi:10.1111/disa.12188

Kato, H., Asukai, N., Miyake, Y., Minakawa, K., & Nishiyama, A. (1996). Post-traumatic symptoms among younger and elderly evacuees in the early stages following the 1995 Hanshin-Awaji earthquake in Japan. *Acta Psychiatr Scand, 93*(6), 477-481.

Kazama, M., & Noda, T. (2012). *Damage statistics (Summary of the 2011 off the Pacific Coast of Tohoku Earthquake damage)* (Vol. 52).

Klenk, J., Kerse, N., Rapp, K., Nikolaus, T., Becker, C., Rothenbacher, D., . . . the Acti, F. E. S. G. (2015). Physical Activity and Different Concepts of Fall Risk Estimation in Older People–Results of the ActiFE-Ulm Study. *PloS one, 10*(6), e0129098. doi:10.1371/journal.pone.0129098

Klinenberg, E. (2002). *Heat wave: A social autopsy of disaster in Chicago*. Chicago, IL: The University of Chicago Press.

Kukihara, H., Yamawaki, N., Uchiyama, K., Arai, S., & Horikawa, E. (2014). Trauma, depression, and resilience of earthquake/tsunami/nuclear disaster survivors of

Hirono, Fukushima, Japan. *Psychiatry Clin Neurosci, 68*(7), 524-533. doi:10.1111/pcn.12159

Labra, O., Maltais, D., & Tremblay, G. (2017). Chilean Men Exposed to the Major Earthquake in 2010:Investigation of the Impacts on Their Health. *American Journal of Men's Health, 11*(2), 392-403. doi:10.1177/1557988316681669

Labra, O., Maltais, D., & Gingras-Lacroix, G. (2018). Medium-Term Health of Seniors Following Exposure to a Natural Disaster. *Inquiry: A Journal of Medical Care Organization, Provision and Financing, 55*, 0046958018766667. doi:10.1177/0046958018766667

Liang, N.-J., Shih, Y.-T., Shih, F.-Y., Wu, H.-M., Wang, H.-J., Shi, S.-F., . . . Wang, B. B. (2001). Disaster epidemiology and medical response in the Chi-Chi earthquake in Taiwan. *Annals of Emergency Medicine, 38*(5), 549-555. doi:10.1067/mem.2001.118999

Link, B. G., & Phelan, J. (1995). Social conditions as fundamental causes of disease. *J Health Soc Behav, Spec No*, 80-94.

Martin, L. G., & Schoeni, R. F. (2014). Trends in Disability and Related Chronic Conditions Among the Forty-and-Over Population: 1997-2010. *Disability and health journal, 7*(1 0), S4-14. doi:10.1016/j.dhjo.2013.06.007

Mirowsky, J., & Ross, C. E. (2003). *Social Causes of Psychological Distress*. New York: Aldine de Druyter.

Morita, T., Nomura, S., Tsubokura, M., Leppold, C., Gilmour, S., Ochi, S., . . . Kami, M. (2017). Excess mortality due to indirect health effects of the 2011 triple disaster in

Fukushima, Japan: a retrospective observational study. *J Epidemiol Community Health, 71*(10), 974-980. doi:10.1136/jech-2016-208652

Musick, M. A., Herzog, A. R., & House, J. S. (1999). Volunteering and mortality among older adults: findings from a national sample. *J Gerontol B Psychol Sci Soc Sci, 54*(3), S173-180.

Niitsu, T., Takaoka, K., Uemura, S., Kono, A., Saito, A., Kawakami, N., . . . Shimizu, E. (2014). The psychological impact of a dual-disaster caused by earthquakes and radioactive contamination in Ichinoseki after the Great East Japan Earthquake. *BMC Research Notes, 7*, 307-307. doi:10.1186/1756-0500-7-307

Pearlin, L. I., Schieman, S., Fazio, E. M., & Meersman, S. C. (2005). Stress, health, and the life course: some conceptual perspectives. *J Health Soc Behav, 46*(2), 205-219. doi:10.1177/002214650504600206

Reconstruction Agency (2018a) Sinsai Kanren Shi no Shishasu ni tsuite (About the number of disaster-related deaths). Retrieved from http://www.reconstruction.go.jp/topics/main-cat2/sub-cat2-6/20140526131634.html.

——— (2018b) Zenkoku no Hinshan no Kazu (The Number of Evacuees Nationwide). Retrieved from http://www.reconstruction.go.jp/topics/main-cat2/sub-cat2-1/hinanshasuu.html

Rofi, A., Doocy, S., & Robinson, C. (2006). Tsunami mortality and displacement in Aceh province, Indonesia. *Disasters, 30*(3), 340-350. doi:10.1111/j.0361-3666.2005.00324.x

Sasaki, Y., Aida, J., Tsuji, T., Miyaguni, Y., Tani, Y., Koyama, S., . . . Kawachi, I. (2018). Does Type of Residential Housing Matter for Depressive Symptoms in the Aftermath of a Disaster? Insights From the Great East Japan Earthquake and Tsunami. *American journal of epidemiology, 187*(3), 455-464. doi:10.1093/aje/kwx274

Seplaki, C. L., Goldman, N., Weinstein, M., & Lin, Y. H. (2006). Before and after the 1999 Chi-Chi earthquake: traumatic events and depressive symptoms in an older population. *Soc Sci Med, 62*(12), 3121-3132. doi:10.1016/j.socscimed.2005.11.059

StataCorp. (2013). Stata Statistical Software: Release 13. College Station, TX: StataCorp LP.

Sugimoto, T., Umeda, M., Shinozaki, T., Naruse, T., & Miyamoto, Y. (2015). Sources of perceived social support associated with reduced psychological distress at 1 year after the Great East Japan Earthquake: Nationwide cross-sectional survey in 2012. *Psychiatry Clin Neurosci, 69*(9), 580-586. doi:10.1111/pcn.12235

Suzuki, S., Sakamoto, S., Koide, M., Fujita, H., Sakuramoto, H., Kuroda, T., . . . Matsuo, T. (1997). Hanshin-Awaji earthquake as a trigger for acute myocardial infarction. *Am Heart J, 134*(5 Pt 1), 974-977.

Tsuboya, T., Aida, J., Hikichi, H., Subramanian, S. V., Kondo, K., Osaka, K., & Kawachi, I. (2016). Predictors of depressive symptoms following the Great East Japan earthquake: A prospective study. *Soc Sci Med, 161*, 47-54. doi:10.1016/j.socscimed.2016.05.026

Tsujiuchi, T., Yamaguchi, M., Masuda, K., Tsuchida, M., Inomata, T., Kumano, H., . . . Mollica, R. F. (2016). High Prevalence of Post-Traumatic Stress Symptoms in Relation to Social Factors in Affected Population One Year after the Fukushima Nuclear Disaster. *PloS one, 11*(3), e0151807. doi:10.1371/journal.pone.0151807

Verbrugge, L. M., & Jette, A. M. (1994). The disablement process. *Soc Sci Med, 38*(1), 1-14.

Yokoyama, Y., Otsuka, K., Kawakami, N., Kobayashi, S., Ogawa, A., Tannno, K., . . . Sakata, K. (2014). Mental Health and Related Factors after the Great East Japan Earthquake and Tsunami. *PloS one, 9*(7), e102497. doi:10.1371/journal.pone.0102497

Table 1

Sample characteristics of the NUJLSOA, 2013

Variables	%/Mean
Dependent variable	
Disabled in 2013	36.04
Disabled between 2009 and 2013	28.96
Independent variable	
Affected by the 2011 East Japan earthquake and tsunami	16.55
Directly affected by the 2011 disaster	10.98
Indirectly affected by the 2011 disaster	11.56
Control variables	
Women	55.41
Age (years)	82.34
Low education	69.87
Economic hardships	34.26
Living alone	12.89
Self-rated health:	
Good	17.66
Fair	49.50
Bad	32.83
Chronic conditions (count)	1.15

Note. Percentages are shown for categorical variables. Mean values are presented for continuous variables.

Table 2
Odds ratios predicting the prevalence of disability in 2013

	Model 1	Model 2
Affected by the Great East Japan earthquake and tsunami in 2011	**1.61 (1.14-2.27)**	**1.54 (0.99- 2.37)**
Women		**1.66 (1.19-2.32)**
Age (years)		**1.20 (1.17-1.24)**
Low education		1.27 (0.89-1.80)
Economic hardships		1.08 (0.76-1.52)
Living alone		1.27 (0.79-2.04)
Self-rated health status		
Good		ref.
Fair		1.70 (1.00-2.88)
Bad		**7.02 (3.99-12.35)**
Chronic conditions (count)		**1.36 (1.19-1.56)**
ADLs in the previous wave of 2009	**5.58 (3.63-8.58)**	**2.79 (1.88-4.14)**
logL	-625.516	-457.162

Note. Control variables come from 2013, except for ADLs in 2009. 95% confidence intervals are in parentheses. Bold statistics indicate significant results ($p<0.5$).

Table 3

Odds ratios predicting the incidence of disability between 2009 and 2013

	Model 1	Model 2
Affected by the Great East Japan earthquake and tsunami in 2011	**1.64 (1.15-2.35)**	**1.54 (1.02-2.34)**
Women		**1.49 (1.07-2.70)**
Age (years)		**1.19 (1.16-1.23)**
Low education		1.16 (0.82-1.65)
Economic hardships		1.01 (0.68-1.50)
Living alone		1.22 (0.77-1.95)
Self-rated health status		
Good		ref.
Fair		1.47 (0.99-2.17)
Bad		**2.49 (1.55-4.00)**
Chronic conditions (count)		**1.38 (1.17-1.62)**
logL	-570.634	-461.456

Note. Control variables are from 2009. 95% confidence intervals are in parentheses. Bold statistics indicate significant results ($p<0.5$).

Table 4

Odds ratios predicting the prevalence of disability in 2013 and incidence of disability between 2009 and 2013

	(1) Prevalence	(2) Incidence
Direct exposure	**1.768**	**1.68**
	(1.06-2.94)	**(1.04-2.73)**
Indirect exposure	1.20	1.31
	(0.72-2.01)	(0.80-2.16)

Note. All models include control variables presented in Tables 2 and 3. 95% confidence intervals are in parentheses. Bold statistics indicate significant results ($p<0.5$).