Tohoku J. Exp. Med., 2023, **261**, 325-333

Association between Social Isolation and the Risk of Incident Functional Disability in Elderly Survivors after the Great East Japan Earthquake

Susumu Tsunoo,[1] Yumi Sugawara[1] and Ichiro Tsuji[1]

[1]Division of Epidemiology, Department of Health Informatics and Public Health, School of Public Health, Tohoku University Graduate School of Medicine, Sendai, Miyagi, Japan

Social isolation is frequently observed among survivors of disaster. However, there is limited evidence regarding the association between social isolation and adverse health outcomes among survivors of disaster. The purpose of this study was to investigate the association between social isolation and the risk of incident functional disability (IFD) among survivors of the 2011 Great East Japan Earthquake (GEJE). We conducted a prospective cohort study of 1,039 residents aged ≥ 65 years who lived in four areas affected by the GEJE. Information regarding social isolation and other lifestyle factors was collected between June and November 2011 via a self-reported questionnaire. Social isolation was assessed using the Lubben Social Network Scale-6 (LSNS-6). Data regarding the incidence of functional disability were retrieved from the Long-term Care Insurance database. The Cox model was used to calculate multivariate hazard ratios (HRs) and 95% confidence intervals (CIs) for IFD. During 7,030 person-years of follow-up, 300 cases of IFD were certified (42.7disability events per 1,000 person-years). Social isolation was associated with increased risk of IFD in disaster survivors (HR = 1.32, 95% CI = 0.98-1.76). In addition, this association tended to be more remarkable among men and those whose houses were completely/seriously damaged. The present results suggest us that it would be possible to identify those who are more likely to be affected by social isolation after disaster. This finding would be useful in screening and supporting high risk group right after the occurrence of disaster.

Keywords: disaster survivors; functional disability; Great East Japan Earthquake; prospective cohort study; social isolation

Tohoku J. Exp. Med., 2023 December, **261** (4), 325-333.
doi: 10.1620/tjem.2023.J084

Introduction

Social isolation is frequently observed among survivors of disaster, for the reasons of loss of family and friends, and relocation from their accustomed place of residence (Riad and Norris 1996; Teasdale et al. 2013; Inoue et al. 2014; Sekiguchi et al. 2019).

Epidemiological evidence suggests that social isolation is associated with adverse health outcomes such as coronary heart disease, stroke, depression, dementia, and mortality in older adults (Holt-Lunstad et al. 2015; Valtorta et al. 2016; Yamada and Arai 2018; Sutin et al. 2020; Lee et al. 2021). A meta-analysis of longitudinal observational studies has reported that social isolation was associated with a 29% increase in the risk of heart disease and a 32% increase in the risk of stroke (Valtorta et al. 2016). A study from the UK reported that loneliness was responsible for 11%-18% of depression symptoms in their participants (Lee et al. 2021). The results of the Health and Retirement Study showed that social isolation was associated with an increase in the risk of dementia of approximately 50% (Sutin et al. 2020). A meta-analysis of 70 studies conducted among the general population concluded that loneliness and social isolation are well-established risk factors for mortality (Holt-Lunstad et al. 2015). Functional disability has been defined as acquired difficulty in performing basic everyday tasks or more complex tasks needed for independent living (Rodrigues et al. 2009). In Japan, nationally uniform crite-

Received June 30, 2023; revised and accepted October 1, 2023; J-STAGE Advance online publication October 12, 2023

Correspondence: Yumi Sugawara, Ph.D., Division of Epidemiology, Department of Health Informatics and Public Health, School of Public Health, Tohoku University Graduate School of Medicine, 2-1 Seiryo-machi, Aoba-ku, Sendai, Miyagi 980-8575, Japan.
e-mail: yumi1717@med.tohoku.ac.jp

ria of functional disability among the elderly are set by the Long-term Care Insurance (LTCI) system, and these criteria are commonly used by Japanese researchers for defining functional disability in large-scale epidemiological studies (Zhang et al. 2016; Saito et al. 2022; Shimizu et al. 2023).

Social isolation may also have the effect of increased risk of functional disability, as was found in a study from China that reported a positive relation between social isolation and functional disability among women (Guo et al. 2021).

There is limited evidence regarding the association between social isolation and adverse health outcomes among survivors of the Great East Japan Earthquake (GEJE). A cohort study has reported an increased risk of mortality in elderly survivors who were socially isolated (Kotozaki et al. 2021); whereas another study has reported that among survivors aged 65 years or older when the 2011 GEJE occurred, socially isolated subjects were more likely to have psychological distress (Sone et al. 2016) that was associated with an increased risk of functional disability (Tanji et al. 2017).

Although the prevalence of disability among the elderly in disaster-stricken areas increased after the GEJE (Tomata et al. 2014, 2015), the association between social isolation and risk of functional disability among survivors after disasters has never been investigated.

The purpose of the present study was to examine the association between social isolation and the risk of functional disability among elderly survivors, and to examine the hypothesis that the prevalence in disability after the GEJE can be partly attributed to social isolation. We would further attempt to elucidate the characteristics of those who are more likely to be affected by social isolation. The findings could help explain the increase in the prevalence of disability after GEJE and promote better planning for disability prevention after disaster.

Methods

Study design and participants

The design of this cohort study is described in detail elsewhere (Sone et al. 2016; Tanji et al. 2017). Baseline health examinations and questionnaires were completed between June and November 2011. The study participants were residents aged ≥ 18 years who were included in the Residential Registry for Ogatsu, Oshika, and Ajishima, of Ishinomaki City, Miyagi Prefecture, and whose houses were largely or totally destroyed by the earthquake and tsunami in Shichigahama Town, Miyagi Prefecture. Written consent, along with a survey form, were obtained from participants both for participation in the study and confirmation of LTCI certification information for the study. The research protocol was reviewed and approved by the Ethics Committee of the Tohoku University Graduate School of Medicine (2011-92, 2017-1-069).

Of the 8,317 subjects, 3,466 (41.7%) participated in the baseline physical examination and questionnaire survey (between June and November 2011). Of the participants, 1,400 were aged ≥ 65 years. For this study, we excluded 198 participants who did not provide written consent for review of their LTCI information, 109 who had already received a disability rating from LTCI, 52 who had not completed the Lubben Social Network Scale-6 (LSNS-6), and 2 who had moved out of the study area. Therefore, the total number of participants in the present analysis was 1,039 (Fig. 1).

Measurements

The questionnaire included items regarding age at baseline survey, sex, house damage, region of residence, type of residence, self-rated health, subjective economic status, social network (Lubben et al. 2006; Kurimoto et al. 2011), smoking status, alcohol consumption, time spent walking, frequency of going out, and psychological distress (Kessler et al. 2002; Furukawa et al. 2008), current medical history (cancer, stroke, myocardial infarction, and kidney disease), and body pain (low back pain, limb arthralgia).

The main exposure was social isolation which was evaluated using the LSNS-6 (Lubben et al. 2006) which comprises six items related to social connections (three questions related to family ties and three questions related to friendship ties), and it is used worldwide as a screening tool for social isolation in elderly individuals. Each item is rated on a 6-point Likert scale; LSNS-6 scores ranged from 0 to 30. The reliability and validity of the Japanese version have been confirmed and social isolation was defined as a score of < 12 (Kurimoto et al. 2011). We divided the participants into two groups: "isolated group" (LSNS-6 score < 12), or "non-isolated group" (LSNS-6 score ≥ 12).

Five options were used to assess house damage that was caused by the GEJE: (1) completely damaged (including all outflows), (2) seriously damaged, (3) half-damaged, (4) partially damaged, and (5) no damage. People whose houses were seriously or completely damaged were more likely to be relocated to other areas, thus weakening their relationships with their original neighbors. We divided the participants into two groups, "completely/seriously damaged" or "half-damaged or less."

Psychological distress was measured using the K6 (6-item Kessler Psychological Distress Scale), which is composed of six items rated from 0 to 4, with a total score ranging from 0 to 24 (Kessler et al. 2002; Furukawa et al. 2008). If the total score on the K6 is ≥ 10, the participant is considered to have a psychological distress.

Follow-up and incident functional disability (IFD)

Incident functional disability (IFD) was defined according to disability certification in the LTCI system by June 30, 2020, regardless of the certification level (Support Levels 1 or higher). LTCI certification is used in Japan as a nationally uniform standard of functional disability. LTCI is a mandatory form of social insurance aimed at assisting activities of daily living (ADL) in the frail and disabled

elderly (Ikegami 1997; Ministry of Health, Labour and Welfare, Japan 2002; Tsutsui and Muramatsu 2005; Imai et al. 2008). All people aged ≥ 40 years pays as premium, and those aged ≥ 65 years are eligible to receive formal caregiving services. When an elderly person needs assistance with ADLs, they apply to the local government for benefits, and a care manager evaluates the degree of functional disability using a questionnaire prepared by the Ministry of Health, Labour and Welfare. The municipality then calculates the standard scores for physical and cognitive disabilities based on the medical questionnaire and a physician's written judgment. The Municipal Certification Committee subsequently reviews the application to determine the eligibility for LTCI benefits. When a person is determined to be eligible in this manner, the Municipal Certification Board determines one of seven levels (Support Levels 1 and 2 and Care Levels 1-5). Briefly, the LTCI certification levels are defined as follows: Support Level 1: "limited in instrumental activities of daily living, but independent in basic ADLs"; Care Level 2: "requires assistance with at least one basic ADL task"; and Care Level 5: "requires assistance with all ADL tasks." Community-based studies have shown that LTCI certification levels correlate well with ability to perform activities of daily living and Mini-Mental State Examination scores (Arai et al. 2003). LTCI certification has been used in many previous studies as an indicator of IFD in the elderly (Tanji et al. 2017; Sone et al. 2021).

All participants were followed up by reviewing information on the date of LTCI certification, death or emigration from Ishinomaki City or Shichigahama Town. All data were transferred from each government under the agreement related to Epidemiologic Research and Privacy Protection (https://www.ch-center.med.tohoku.ac.jp/report-pdf/h24-report.pdf). The person-years of follow-up were counted from the first date of the baseline survey at each site (Ogatsu: June 24, 2011; Oshika: August 7, 2011; Ajishima: September 10, 2011; Shichigahama: November 18, 2011) until the date of IFD, emigration from any of these areas, death, or end of the study period (June 30, 2020), whichever came first. We discontinued follow-up of participants who had moved outside of the study municipalities; because we were unable to review information regarding the date of LTCI certification or the Residential Records from outside the study area. In present study, 5.4% of subjects were lost to follow-up.

Statistical analysis

Kaplan-Meier estimates were used to compare the proportion of participants remaining free from functional disability during follow-up period between the socially isolated and non-isolated groups.

We used the multiple adjusted Cox proportional hazards models to estimate the hazard ratio (HR) and 95% con-

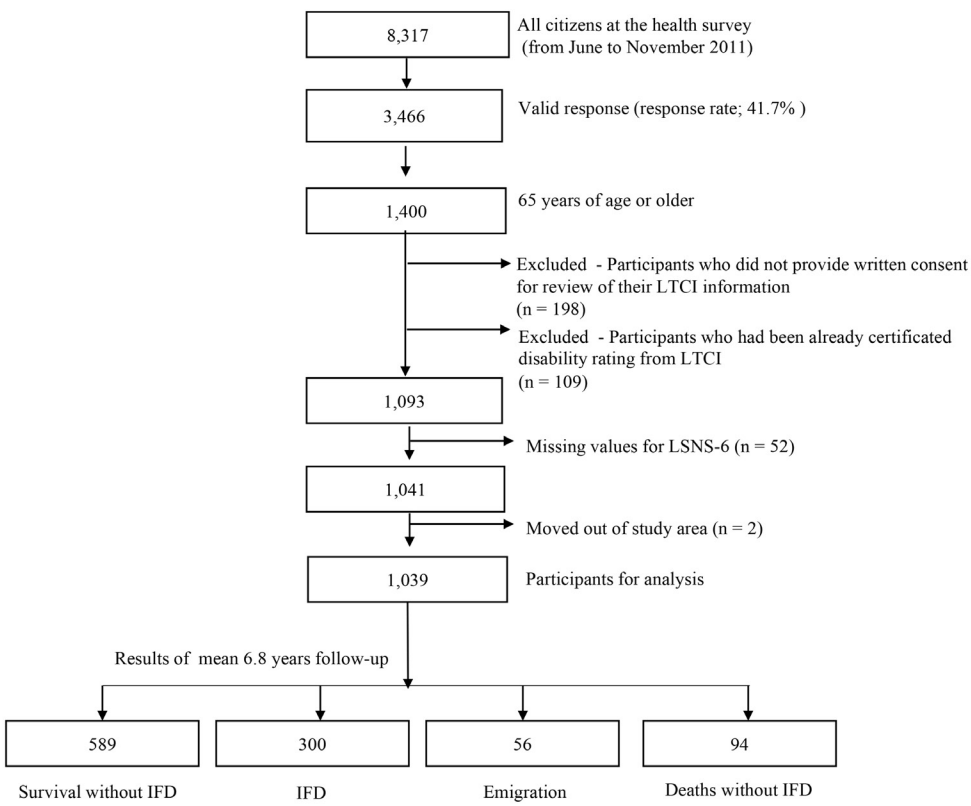

Fig. 1. Flow chart of the study participants.
LTCI, Long-term Care Insurance; LSNS-6, Lubben Social Network Scale-6; IFD, incident functional disability.

Table 1. Baseline characteristics according to social isolation.

	Social isolation (LSNS-6 score)		*p* value
	not socially isolated (≥ 12)	socially isolated (< 12)	
No. of subjects	836	203	
Sex (%)			
Men	44.7	50.7	0.12
Women	55.3	49.3	
Age at baseline survey (SD)	74.2 ± 5.6	74.5 ± 6.2	0.61
House damage (%)			
Completely/seriously damaged	60.9	65.8	0.37
Ishinomaki	31.4	37.3	
Shichigahama	29.5	28.5	
Half-damaged or less	39.1	34.2	
Ishinomaki	39.1	34.2	
Shichigahama	-	-	
Type of residence (%)			
Same house as that before the earthquake	48.0	45.5	0.75
Shelter or temporary/rental housing	34.3	33.7	
House of family member, relative or friend	1.1	1.0	
Current medical history (%)			
Stroke	1.7	1.5	0.84
Myocardial infarction/angina pectoris	8.0	10.8	0.20
Kidney disease	1.3	1.0	0.70
Cancer	5.1	2.5	0.10
Economic status (%)			
Very hard/hard	77.3	74.9	0.47
A little hard/normal	22.7	25.1	
Self-rated health (%)			
Very good/good	80.9	72.0	< 0.05
Poor/ very poor	19.1	28.0	
Smoking (%)			
Non-smoking	91.3	85.7	< 0.05
Currently smoking	8.8	14.3	
Alcohol consumption (%)			
Non-drinking	70.4	68.2	0.55
Currently drinking	29.6	31.8	
Psychological distress (K6 score) (%)			
< 10	86.4	79.2	< 0.05
≥ 10	13.6	20.8	
Frequency of going out (%)			
every day	43.7	36.6	< 0.05
3 days/week	26.6	20.8	
≤ 1 day/week	29.7	42.6	

LSNS-6, Lubben Social Network Scale-6; SD, standard deviation; K6, 6-item Kessler Psychological Distress Scale.

fidence interval (CI) for IFD related to social isolation (LSNS-6 score < 12; isolated group), using those categorized as not socially isolated (LSNS-6 score ≥ 12; non-isolated group) as the reference. Multivariate models were adjusted for the following variables. Model 1 was adjusted for sex (male or female), age at baseline survey (continuous variable), study region (Ogatsu, Oshika, Ajishima, or Shichigahama), type of residence [the same house as that before the earthquake (no relocation), shelter or temporary/rental housing, house of family member, relative or friend, or other], current medical history (stroke, myocardial infarction/angina pectoris, kidney disease, or cancer), smoking status (non-smoker or current smoker), alcohol consumption (non-drinker or current drinker), and fre-

quency of going out (every day, 3 days/week, or ≤ 1 day/week). Model 2 was further adjusted for the K6 score (< 10, or ≥ 10) because psychological distress may affect the association between social isolation and IFD. The effect of modification between social isolation and all confounders was tested through the addition of cross-product terms to the multivariate model.

We also conducted a sensitivity analysis to investigate the association between social isolation and the risk of IFD by changing the criteria for disability certification (Care Levels ≥ 2).

We also conducted stratified analyses according to sex (male or female), age at baseline survey (< 75 or ≥ 75 years), house damage (completely/seriously damaged or half-damaged or less), self-rated health (very good/good or poor/very poor), smoking (non-smoker or current smoker), frequency of going out (≥ 3 days/week or < 3 days/week) and psychological distress (K6 score; < 10 or ≥ 10).

Moreover, we examined the association between social isolation and IFD according to the degree of house damage and by sex.

All statistical analyses were performed using the SAS software package (version 9.4; SAS Institute, Inc., Cary, NC, USA). All statistical tests were 2-sided, and differences of $p < 0.05$ were taken as significant.

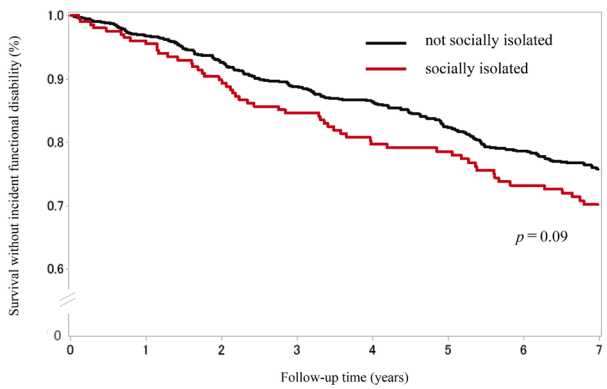

Fig. 2. Kaplan-Meier curves for survival without incident functional disability by social isolation.

Results

During the mean 6.8 years of follow-up (7,030 person-years), there were 300 new certifications of disability (42.7 disability events per 1,000 person-years), 94 subjects died without any certification of disability, and 56 subjects (5.4%) were lost to follow-up because they moved away from the study area.

Participant characteristics

Baseline characteristics according to each category of the LSNS-6 are shown in Table 1. Among the 1,039 participants, the mean age (SD) was 74.3 (5.8) years, 45.9% were men, and 203 (19.5%) were socially isolated (LSNS-6 score < 12). The ratio of males to females for people aged ≥ 65 years in our study population (45.9%/54.1%) was similar to that of Ishinomaki City (41.4%/58.6%) and that of Japanese (42.6%/57.4%). Socially isolated participants were more likely to have poor self-rated health, to be current smokers, to report psychological distress (K6 score ≥ 10), and were less likely to go out every day.

Social isolation and functional disability

Kaplan-Meier analysis showed that survival without IFD after the GEJE was lower in the socially isolated group than in the non-isolated group (Fig. 2). Table 2 shows the association between social isolation and the risk of IFD. Risk was significantly higher in the socially isolated group (LSNS-6 score < 12) (model 1; HR = 1.33, 95% CI = 1.00-1.79) than in the not socially isolated group (LSNS-6 score ≥ 12). To consider the possibility that psychological distress at baseline might affect the association between social isolation and the risk of IFD, we made the model 2 in which K6 score was added as a covariate. We observed the association between social isolation and the risk of IFD did not

Table 2. Relationships between social isolation and incident functional disability.

	Social isolation (LSNS-6 score)	
	not socially isolated (≥ 12)	socially isolated (< 12)
No. of subjects	836	203
Person-years	5,746	1,283
No. of cases	239	61
Model 1[a] (95% CI)	1.00 (ref)	1.33 (1.00-1.79)
Model 2[b] (95% CI)	1.00 (ref)	1.32 (0.98-1.76)

[a]Model 1; adjusted for sex (male, or female), age at baseline survey (continuous variable), study region (Ogatsu, Oshika, Ajishima, or Shichigahama), type of residence (same house as that before the earthquake, shelter or temporary/rental housing, house of family member, relative or friend, or others), current medical history (stroke, myocardial infarction/angina pectoris, kidney disease, or cancer), smoking status (non-smoking, or currently smoking), alcohol consumption (non-drinking, or currently drinking), and frequency of going out (every day, 3 days/week, or ≤ 1 day/week).

[b]Model 2; adjusted for Model 1 plus psychological distress (K6 score ; < 10, or ≥ 10).

LSNS-6, Lubben Social Network Scale-6; CI, confidence intervals; K6, 6-item Kessler Psychological Distress Scale.

Table 3. Stratified analyses: the association between social isolation and incident functional disability risk.

	Social isolation (LSNS-6 score)		*p*-interaction
	not socially isolated	socially isolated	
Sex			
Male			
No. of cases of incident disability/subjects	98/374	28/103	
Model 1[a] (95% CI)	1.00 (ref)	1.61 (1.03-2.52)	
Model 2[b] (95% CI)	1.00 (ref)	1.58 (1.01-2.47)	
Female			0.74
No. of cases of incident disability/subjects	141/462	33/100	
Model 1[a] (95% CI)	1.00 (ref)	1.20 (0.81-1.78)	
Model 2[b] (95% CI)	1.00 (ref)	1.19 (0.80-1.77)	
Age at baseline survey			
< 75 years			
No. of cases of incident disability/subjects	66/481	16/112	
Model 1[a] (95% CI)	1.00 (ref)	1.35 (0.77-2.36)	
Model 2[b] (95% CI)	1.00 (ref)	1.33 (0.76-2.34)	
≥ 75 years			0.32
No. of cases of incident disability/subjects	173/355	45/91	
Model 1[a] (95% CI)	1.00 (ref)	1.34 (0.96-1.88)	
Model 2[b] (95% CI)	1.00 (ref)	1.33 (0.95-1.86)	
House damage			
Completely/seriously damaged			
No. of cases of incident disability/subjects	115/452	31/103	
Model 1[a] (95% CI)	1.00 (ref)	1.62 (1.07-2.45)	
Model 2[b] (95% CI)	1.00 (ref)	1.61 (1.06-2.43)	
Half-damaged or less			0.33
No. of cases of incident disability/subjects	85/261	19/58	
Model 1[a] (95% CI)	1.00 (ref)	1.17 (0.70-1.93)	
Model 2[b] (95% CI)	1.00 (ref)	1.13 (0.68-1.87)	
Self-rated health			
Very good/good			
No. of cases of incident disability/subjects	180/662	40/144	
Model 1[a] (95% CI)	1.00 (ref)	1.08 (0.76-1.55)	
Model 2[b] (95% CI)	1.00 (ref)	1.06 (0.74-1.51)	
Poor/ very poor			0.02
No. of cases of incident disability/subjects	55/156	21/56	
Model 1[a] (95% CI)	1.00 (ref)	2.08 (1.18-3.68)	
Model 2[b] (95% CI)	1.00 (ref)	2.03 (1.14-3.60)	
Smoking			
Non-smoking			
No. of cases of incident disability/subjects	216/720	54/168	
Model 1[a] (95% CI)	1.00 (ref)	1.32 (0.97-1.79)	
Model 2[b] (95% CI)	1.00 (ref)	1.30 (0.96-1.78)	
Currently smoking			0.15
No. of cases of incident disability/subjects	9/69	1/28	
Model 1[a] (95% CI)	1.00 (ref)	0.30 (0.03-2.60)	
Model 2[b] (95% CI)	1.00 (ref)	0.31 (0.03-2.95)	
Psychological distress (K6 score)			
< 10			
No. of cases of incident disability/subjects	199/696	43/156	
Model 1[a] (95% CI)	1.00 (ref)	1.09 (0.78-1.54)	

Model 2[b] (95% CI)	1.00 (ref)	—	
≥ 10			0.12
No. of cases of incident disability/subjects	34/110	15/41	
Model 1[a] (95% CI)	1.00 (ref)	1.84 (0.96-3.53)	
Model 2[b] (95% CI)	1.00 (ref)	—	
Frequency of going out			
≥ 3 days/week			
No. of cases of incident disability/subjects	140/586	32/116	
Model 1[a] (95% CI)	1.00 (ref)	1.26 (0.84-1.91)	
Model 2[b] (95% CI)	1.00 (ref)	1.23 (0.82-1.86)	
< 3 days/week			0.33
No. of cases of incident disability/subjects	97/247	28/86	
Model 1[a] (95% CI)	1.00 (ref)	1.22 (0.79-1.91)	
Model 2[b] (95% CI)	1.00 (ref)	1.22 (0.78-1.90)	

[a]Model 1; adjusted for sex (male, or female), age at baseline survey (continuous variable), study region (Ogatsu, Oshika, Ajishima, or Shichigahama), type of residence (same house as that before the earthquake, shelter or temporary/rental housing, house of family member, relative or friend, or others), current medical history (stroke, myocardial infarction/angina pectoris, kidney disease, or cancer), smoking status (non-smoking, or currently smoking), alcohol consumption (non-drinking, or currently drinking), and frequency of going out (every day, 3 days/week, or ≤ 1 day/week).

[b]Model 2; adjusted for Model 1 plus psychological distress (K6 score ; < 10, or ≥ 10).

LSNS-6, Lubben Social Network Scale-6; CI, confidence intervals; K6, 6-item Kessler Psychological Distress Scale.

change, although it was not significant (model 2; HR = 1.32, 95% CI = 0.98-1.76).

The sensitivity analysis using Care Levels ≥ 2 as the criteria for disability confirmed the association between social isolation and IFD risk, although the association was not significant (model 1; HR = 1.42, 95% CI = 0.85-2.37, model 2; HR = 1.39, 95% CI = 0.83-2.32) (Supplementary Table S1).

Table 3 shows stratified analyses of the association between social isolation and the risk of IFD according to sex, age at baseline survey, house damage, self-rated health, smoking, frequency of going out, and psychological distress. A significant association between social isolation and increased risk of IFD was observed among men (model 2; HR = 1.58, 95% CI = 1.01-2.47) but not among women (HR = 1.19, 95% CI = 0.80-1.77), among participants whose houses were completely/seriously damaged (HR = 1.61, 95% CI = 1.06-2.43) but not among those whose houses were half-damaged or less (HR = 1.13, 95% CI = 0.68-1.87), among those who had poor/very poor self-rated health (HR = 2.03, 95% CI = 1.14-3.60) but not among those had very good/good self-rated health (HR = 1.06, 95% CI = 0.74-1.51). Also, in the high distress group (K6 score ≥ 10), social isolation was associated with an 84% increase in the risk of IFD (HR = 1.84, 95% CI = 0.96-3.53).

Table 4 shows the association between social isolation and the risk of IFD according to the degree of house damage and by sex. In men, social isolation was associated with IFD, irrespective of the degrees of house damage (completely/seriously damaged; model 2; HR = 1.68, 95% CI = 0.89-3.21, half-damaged or less; HR = 1.45, 95% CI = 0.72-2.95). In women, only participants whose houses were completely/seriously damaged tended to be associated with an increased risk (HR = 1.61, 95% CI = 0.92-2.81).

Discussion

We investigated the association between social isolation and the risk of IFD in elderly survivors after the GEJE using prospective cohort data. The findings revealed that social isolation was associated with increased risk of functional disability in disaster survivors. This relation was more remarkable in men than women. A Chinese study concerning the general population also showed that social isolation was significantly associated with functional status among women (OR = 1.18, 95% CI = 1.07-1.30), but not men (Guo et al. 2021). Their results were opposite to ours. The reason for this inconstancy is not clear, but it could be attributable to the differences between the types of study participants: the general population in the Chinese study and disaster survivors in ours. Sex differences regarding the impact of social isolation may differ between usual and post disaster situations.

In this study, we elucidated the characteristics of those more likely to be affected by social isolation. Men, participants whose houses were completely/seriously damaged, those who had poor self-rated health, and those who had psychological distress tended to be more affected. Although we have no data or evidence to discuss causal relationship, we were able to identify the high-risk group. This finding would be useful in screening and supporting high risk group right after the occurrence of disaster.

These findings suggest the necessity of providing a comprehensive support program, including psycho-social support and disability prevention, for affected people of disaster whose houses have been severe damaged.

Table 4. Relationships between social isolation and incident functional disability according house damage by sex.

	Male (n = 399)		Female (n = 475)		*p*-interaction
	not socially isolated	socially isolated	not socially isolated	socially isolated	
House damage					
Completely/seriously damaged					
Number of subjects	213	53	239	50	
Person-years	1,524	343	1,657	283	
No. of cases	50	13	65	18	
Model 1[a] (95% CI)	1.00 (ref)	1.66 (0.87-3.18)	1.00 (ref)	1.58 (0.91-2.76)	0.64
Model 2[b] (95% CI)	1.00 (ref)	1.68 (0.89-3.21)	1.00 (ref)	1.61 (0.92-2.81)	0.65
Half-damaged or less					
Number of subjects	104	29	157	29	
Person-years	731	187	1,086	199	
No. of cases	34	11	51	8	
Model 1[a] (95% CI)	1.00 (ref)	1.54 (0.76-3.11)	1.00 (ref)	1.02 (0.48-2.17)	0.40
Model 2[b] (95% CI)	1.00 (ref)	1.45 (0.72-2.95)	1.00 (ref)	0.93 (0.43-1.98)	0.37

[a]Model 1; adjusted for sex (male, or female), age at baseline survey (continuous variable), study region (Ogatsu, Oshika, Ajishima, or Shichigahama), type of residence (same house as that before the earthquake, shelter or temporary/rental housing, house of family member, relative or friend, or others), current medical history (stroke, myocardial infarction/angina pectoris, kidney disease, or cancer), smoking status (non-smoking, or currently smoking), alcohol consumption (non-drinking, or currently drinking), and frequency of going out (every day, 3 days/week, or ≤ 1 day/week).
[b]Model 2; adjusted for Model 1 plus psychological distress (K6 score ; < 10, or ≥ 10).
CI, confidence intervals; K6, 6-item Kessler Psychological Distress Scale.

The present study had several strengths. First, it is the only study thus far to have examined the association between social isolation and the risk of IFD among survivors of a major disaster using prospective data. Second, IFD was confirmed through LTCI certification in Japan, which is a nationally uniform standard of functional disability. Third, a number of confounding factors were considered.

This study also had several limitations. First, social isolation was ascertained only once, at the time of the baseline health survey, using a self-reported questionnaire. Therefore, change in social isolation during the follow-up period is unknown. Second, we did not take into account changes in participants' lifestyle characteristics or psychological status during the follow-up period. Third, we did not account for all potential confounding factors. In socially isolated older adults, environmental factors that cause frailty (i.e., nutrition, exercise, and conversations) might be associated with increased risk of IFD. Fourth, the causes of participants' need for long-term care were not investigated. Finally, not all persons who require long-term care apply for certification in the LTCI system. In particular, those who are isolated might not apply for certification because they do not have anyone to help them apply, and the government and medical institutions cannot detect isolated people. Therefore, the results may have underestimated the association between social isolation and the risk of IFD.

In conclusion, the present findings suggest that social isolation was associated with increased risk of IFD in disaster survivors. In addition, this association tended to be more remarkable among men and those whose houses were completely/seriously damaged. The present results suggest us that it would be possible to identify those who are more likely to be affected by social isolation after disaster. This finding would be useful in screening and supporting high risk group right after the occurrence of disaster.

Acknowledgments

This study was supported by a Health Sciences Research Grant for Health Services [H23-Tokubetsu-Shitei-002, H24-Kenki-Shitei-002, H25-Kenki-Shitei-002 (Fukko)], Ministry of Health, Labour and Welfare, Japan, and a Grant-in-Aid for Scientific Research (A; 21H04845) from Japan Society for the Promotion of Science.

The authors would like to thank members of Center for Community Health, Tohoku University Graduate School of Medicine for technical assistance.

Author Contributions

S.T. designed the research and wrote the initial draft of the manuscript. Y.S. contributed to data collection, analysis and interpretation of data, and assisted in the preparation of the manuscript. I.T. have contributed to data collection and interpretation, and critically reviewed the manuscript. All authors read and approved the final version of the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

References

Arai, Y., Zarit, S.H., Kumamoto, K. & Takeda, A. (2003) Are there inequities in the assessment of dementia under Japan's LTC insurance system? *Int. J. Geriatr. Psychiatry*, **18**, 346-352.

Furukawa, T.A., Kawakami, N., Saitoh, M., Ono, Y., Nakane, Y., Nakamura, Y., Tachimori, H., Iwata, N., Uda, H., Nakane, H., Watanabe, M., Naganuma, Y., Hata, Y., Kobayashi, M., Miyake, Y., et al. (2008) The performance of the Japanese version of the K6 and K10 in the World Mental Health Survey Japan. *Int. J. Methods Psychiatr. Res.*, **17**, 152-158.

Guo, L., An, L., Luo, F. & Yu, B. (2021) Social isolation, loneliness and functional disability in Chinese older women and men: a longitudinal study. *Age Ageing*, **50**, 1222-1228.

Holt-Lunstad, J., Smith, T.B., Baker, M., Harris, T. & Stephenson, D. (2015) Loneliness and social isolation as risk factors for mortality: a meta-analytic review. *Perspect. Psychol. Sci.*, **10**, 227-237.

Ikegami, N. (1997) Public long-term care insurance in Japan. *JAMA*, **278**, 1310-1314.

Imai, H., Fujii, Y., Fukuda, Y., Nakao, H. & Yahata, Y. (2008) Health-related quality of life and beneficiaries of long-term care insurance in Japan. *Health Policy*, **85**, 349-355.

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**, 333-340.

Kessler, R.C., Andrews, G., Colpe, L.J., Hiripi, E., Mroczek, D.K., Normand, S.L., Walters, E.E. & Zaslavsky, A.M. (2002) Short screening scales to monitor population prevalences and trends in non-specific psychological distress. *Psychol. Med.*, **32**, 959-976.

Kotozaki, Y., Tanno, K., Sakata, K., Takusari, E., Otsuka, K., Tomita, H., Sasaki, R., Takanashi, N., Mikami, T., Hozawa, A., Nakaya, N., Tsuchiya, N., Nakamura, T., Narita, A., Taki, Y., et al. (2021) Association between the social isolation and depressive symptoms after the great East Japan earthquake: findings from the baseline survey of the TMM CommCohort study. *BMC Public Health*, **21**, 925.

Kurimoto, A., Awata, S., Ohkubo, T., Tsubota-Utsugi, M., Asayama, K., Takahashi, K., Suenaga, K., Satoh, H. & Imai, Y. (2011) Reliability and validity of the Japanese version of the abbreviated Lubben Social Network Scale. *Nihon Ronen Igakkai Zasshi*, **48**, 149-157 (in Japanese).

Lee, S.L., Pearce, E., Ajnakina, O., Johnson, S., Lewis, G., Mann, F., Pitman, A., Solmi, F., Sommerlad, A., Steptoe, A., Tymoszuk, U. & Lewis, G. (2021) The association between loneliness and depressive symptoms among adults aged 50 years and older: a 12-year population-based cohort study. *Lancet Psychiatry*, **8**, 48-57.

Lubben, J., Blozik, E., Gillmann, G., Iliffe, S., von Renteln Kruse, W., Beck, J.C. & Stuck, A.E. (2006) Performance of an abbreviated version of the Lubben Social Network Scale among three European community-dwelling older adult populations. *Gerontologist*, **46**, 503-513.

Ministry of Health, Labour and Welfare, Japan (2002) Long-term Care Insurance in Japan. https://www.mhlw.go.jp/english/topics/elderly/care/ [*Accessed*: May 20, 2023].

Riad, J. K., & Norris, F. H. (1996) The influence of relocation on the environmental, social, and psychological stress experienced by disaster victims. *Environment and Behavior,* **28**, 163-182.

Rodrigues, M.A., Facchini, L.A., Thume, E. & Maia, F. (2009) Gender and incidence of functional disability in the elderly: a systematic review. *Cad. Saude Publica*, **25** Suppl 3, S464-476.

Saito, J., Murayama, H., Ueno, T., Saito, M., Haseda, M., Saito, T., Kondo, K. & Kondo, N. (2022) Functional disability trajectories at the end of life among Japanese older adults: findings from the Japan Gerontological Evaluation Study (JAGES). *Age Ageing*, **51**, afac260.

Sekiguchi, T., Hagiwara, Y., Sugawara, Y., Tomata, Y., Tanji, F., Yabe, Y., Itoi, E. & Tsuji, I. (2019) Moving from prefabricated temporary housing to public reconstruction housing and social isolation after the Great East Japan Earthquake: a longitudinal study using propensity score matching. *BMJ Open*, **9**, e026354.

Shimizu, Y., Inoue, M., Yasuda, N., Yamagishi, K., Iwasaki, M., Tsugane, S. & Sawada, N. (2023) Bowel movement frequency, stool consistency, and risk of disabling dementia: a population-based cohort study in Japan. *Public Health*, **221**, 31-38.

Sone, T., Nakaya, N., Sugawara, Y., Tomata, Y., Watanabe, T. & Tsuji, I. (2016) Longitudinal association between time-varying social isolation and psychological distress after the Great East Japan Earthquake. *Soc. Sci. Med.*, **152**, 96-101.

Sone, T., Sugawara, Y., Tanji, F., Nakaya, N., Tomita, H. & Tsuji, I. (2021) The association between psychological distress and risk of incident functional disability in elderly survivors after the Great East Japan Earthquake: the mediating effect of lifestyle and bodily pain. *J. Affect. Disord.*, **295**, 552-558.

Sutin, A.R., Stephan, Y., Luchetti, M. & Terracciano, A. (2020) Loneliness and risk of dementia. *J. Gerontol. B Psychol. Sci. Soc. Sci.*, **75**, 1414-1422.

Tanji, F., Sugawara, Y., Tomata, Y., Watanabe, T., Sugiyama, K., Kaiho, Y., Tomita, H. & Tsuji, I. (2017) Psychological distress and the incident risk of functional disability in elderly survivors after the Great East Japan Earthquake. *J. Affect. Disord.*, **221**, 145-150.

Teasdale, B., Stephens, P.C., Sloboda, Z., Stephens, R.C. & Grey, S.F. (2013) The effect of Hurricane Katrina on adolescent feelings of social isolation. *Soc. Sci. Q.*, **94**, 490-505.

Tomata, Y., Kakizaki, M., Suzuki, Y., Hashimoto, S., Kawado, M. & Tsuji, I. (2014) Impact of the 2011 Great East Japan Earthquake and Tsunami on functional disability among older people: a longitudinal comparison of disability prevalence among Japanese municipalities. *J. Epidemiol. Community Health*, **68**, 530-533.

Tomata, Y., Suzuki, Y., Kawado, M., Yamada, H., Murakami, Y., Mieno, M.N., Shibata, Y., Ojima, T., Hashimoto, S. & Tsuji, I. (2015) Long-term impact of the 2011 Great East Japan Earthquake and tsunami on functional disability among older people: a 3-year longitudinal comparison of disability prevalence among Japanese municipalities. *Soc. Sci. Med.*, **147**, 296-299.

Tsutsui, T. & Muramatsu, N. (2005) Care-needs certification in the long-term care insurance system of Japan. *J. Am. Geriatr. Soc.*, **53**, 522-527.

Valtorta, N.K., Kanaan, M., Gilbody, S., Ronzi, S. & Hanratty, B. (2016) Loneliness and social isolation as risk factors for coronary heart disease and stroke: systematic review and meta-analysis of longitudinal observational studies. *Heart*, **102**, 1009-1016.

Yamada, M. & Arai, H. (2018) Social frailty predicts incident disability and mortality among community-dwelling Japanese older adults. *J. Am. Med. Dir. Assoc.*, **19**, 1099-1103.

Zhang, S., Tomata, Y., Sugiyama, K., Kaiho, Y., Honkura, K., Watanabe, T., Tanji, F., Sugawara, Y. & Tsuji, I. (2016) Body mass index and the risk of incident functional disability in elderly Japanese: The OHSAKI Cohort 2006 Study. *Medicine* (*Baltimore*), **95**, e4452.

Supplementary Files

Please find supplementary file(s);
https://doi.org/10.1620/tjem.2023.J084