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[Original article]

Socioeconomic status, damage-related conditions, and PTSD following the Fukushima-daiichi nuclear power plant accident : The Fukushima Health Management Survey

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Abstract

The Great East Japan Earthquake severely damaged the Tohoku and Kanto districts, and Fukushima Prefecture faced a subsequent nuclear disaster. Few studies have reported the effects of socioeconomic stressors on individuals' mental status following disasters. We analyzed the responses of 60,704 adult residents of a designated restricted area to the PTSD Checklist-Stressor-Specific Version (PCL-S). The relationships between the PCL-S scores and demographic, socioeconomic, and damage-related variables were analyzed using regression analysis to predict participants' severity of PTSD symptoms. Approximately 14.1% of evacuees had severe PTSD symptoms (PCL-S ≥50) eighteen months post-earthquake. The PCL-S scores were higher among women, older adults, less educated people, those with a history of mental illness, and those living outside Fukushima Prefecture. The PCL-S scores increased with participants' scores on the Kessler Psychological Distress Scale. The number of trauma-exposure stressors and socioeconomic stressors were associated with 1.52 and 3.77 increases in the PCL-S score, respectively. Furthermore, psychological distress, unemployment, decreased income, house damage, tsunami experience, nuclear power plant accident experience, and loss of someone close due to the disaster were associated with the prevalence of severe PTSD symptoms. The complex triple disaster of a major earthquake, tsunami, and nuclear accident created significant socioeconomic changes that may be important determinants of PTSD among residents of restricted access areas in Fukushima.

Key words : post-traumatic stress disorder, depression, cross-sectional study, population, the Great East Japan Earthquake

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Introduction

The Great East Japan Earthquake of March 11, 2011 had a recorded moment magnitude (M_w) of 9.0. The seismic center was approximately 130 kilometers southeast of the Oshika Peninsula, Miyagi Prefecture. This earthquake triggered a huge tsunami that severely damaged the Pacific coast of both the Tohoku and Kanto districts. The number of dead and missing people due to the earthquake and tsunami is, as of now, over 18,000, with over 400,000 houses partially or totally destroyed[1]. The Fukushima Daiichi Nuclear Power Plant, located on the border of Okuma Town and Futaba Town, Fukushima Prefecture, lost redundant sources of power due to the earthquake and tsunami, which led to a Level 7 (major) nuclear accident, as measured on the International Nuclear Event Scale, according to the International Atomic Agency (IAEA)[2]. The nuclear reactor meltdown and resultant hydrogen explosions caused radioactive contaminants to spread over large areas, mainly in Fukushima Prefecture. As a result, Fukushima residents have experienced long-term environmental effects of these radioactive substances.

Studies of past nuclear accidents, such as Chernobyl and Three Mile Island, have indicated that the most critical health problems caused by such accidents were mental-health issues[3,4]. Among those who lived in areas exposed to radiation, there was a higher prevalence of depression, anxiety (including posttraumatic symptoms), and medically unexplained physical symptoms[5]. Likewise, the World Health Organization (WHO) concluded that mental-health problems were the most serious of all of the health problems following the 2011 disaster in Japan[6].

Because Fukushima residents experienced a triple disaster of earthquake, tsunami, and nuclear accident, many of them had no choice but to evacuate their hometowns, and many remained evacuees three years later. The living conditions of these evacuees in the future remain uncertain. Psychiatric epidemiological surveys following past disasters have revealed a number of risk factors for disaster victims[7]. In this triple disaster, however, the added possibility of health distress due to radiation exposure likely affected residents' long-term mental health considerably, in addition to the previously identified risk factors. Even medical assistance team-workers showed psychological distress concerning radiation exposure after March 2011[8].

Many surveys have revealed that survivors of natural disasters, such as earthquakes and tsunamis, often present with posttraumatic stress disorder (PTSD). However, for man-made disasters, such as the Chernobyl nuclear reactor accident and the 9/11 World Trade Center terrorist attacks, studies have found that PTSD occurs in both local residents and disaster-relief workers[3,4].

As long-term mental-health care was considered important for increasing survivors' capacity for resilience in post-Fukushima recovery, an epidemiological survey (the "Mental Health and Lifestyle Survey") was conducted as part of the Fukushima Health Management Survey. It aimed to ascertain the psychological consequences that followed this nuclear accident and to provide appropriate care to the Fukushima residents[9]. This study's purpose was twofold : (1) to examine the relationships between PTSD symptoms and socioeconomic status and damage-related situations using data obtained from the Fukushima Health Management Survey of Fiscal Year 2011, and (2) to identify possible directions for future studies and support implementation efforts.

Materials and methods

Design

This study analyzed data from the initial year of the Fukushima Health Management Survey conducted 18 months after the earthquake, administered to Fukushima residents who survived the earthquake and faced mandatory evacuation from their residence because of the Fukushima Daiichi Nuclear Power Plant accident. This cross-sectional health survey was used to assess effects of the nuclear accident and accompanying changes in living status experienced by these long-term refugees. The survey's details are provided in Yasumura *et al.*[9]. In the present cross-sectional study, we used data from adults (15 years old and over at the time of the earthquake) who completed the Fukushima Health Management Survey 18 months after the disaster.

This survey and study were approved by the Ethics Committee of Fukushima Medical University (#1316).

Participants

The survey population consisted of 210,189 officially registered residents of a nationally designated restricted area ; all of them were identified as candidates for participation in the survey. The

number of adults born before April 1, 1995, was 180,604 (88,085 men and 92,519 women ; 78,245 persons were aged 15–49 years ; 49,139 were aged 50–64 years ; and 53,220 were 65 years and above). The registered earthquake restricted area included 13 municipalities : Hirono Town, Naraha Town, Tomioka Town, Kawauchi Village, Okuma Town, Futaba Town, Namie Town, Katsurao Village, Iitate Village, Minamisoma City, Tamura Town, Kawamata Town, and part of Date City.

Figure 1 shows this study's participant selection process. We mailed 180,604 questionnaires from the end of January to the beginning of February 2012, to house addresses that were current at the time of the survey, regardless of whether the present address was inside or outside of Fukushima Prefecture. By the end of October 2012, 73,569 questionnaires were returned with responses (40.7% response rate) and 70,193 of these questionnaires (95.4%) had been returned by the end of March 2012. Of these, 12,865 were excluded from the analysis (136 were blank or duplicates ; 9,245 were completed by a proxy, and 3,484 had more than one missing value on the PTSD Checklist–Stressor Specific Version [PCL–S]). If there was only one PCL–S value missing, we substituted the missing value with the average value of the 16 remaining items. In all, we used data from 60,704 participants (26,752 men and 33,952 women ; 22,505 respondents were aged 15–49 years ; 19,542 were 50–64 years ; 18,657 were 65 years and above) (Table 1). The response rates of each restricted area were 35.1% in Hirono, 42.1% in Naraha, 45.0% in Tomioka, 43.3% in Kawauchi, 48.0% in Okuma, 50.0% in Futaba, 51.8% in Namie, 53.4% in Katsurao, 41.6% in Iitate, 40.4% in Minamisoma, 31.2% in Tamura, 37.7% in Kawamata, and 39.9% in part of Date ; comparatively higher response rates are associated with municipalities around the nuclear power plant.

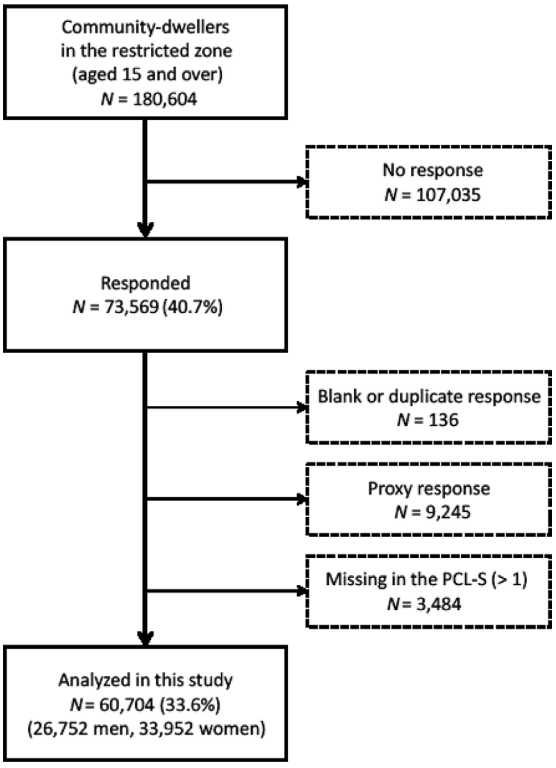

Figure 1. Flowchart of the study's target population.

Data collection and measurements

PTSD Checklist–Stressor Specific Version. The PCL–S was used to evaluate PTSD symptoms. This scale is a 17–item self–report checklist based on the Diagnostic and Statistical Manual of Mental Disorders, 4th edition (DSM–IV) criteria[10], and each item is rated using a Likert–type scale from 1 (*not at all*) to 5 (*extremely*)[11]. Respondents are requested to answer all items by indicating the degree to which they have experienced various PTSD symptoms over the past month. The total PCL–S score, which is calculated by summing the ratings for each item, ranges from 17 to 85.

In addition to the PCL–S, the following items were included on the self–assessment and self–report questionnaires.

Demographic and background characteristics. The participants' characteristics were sex, age group, educational attainment, history of mental illness, and mental–health status. Age groups were divided into childbearing age (15–49 years), middle age (50–64 years), and old age (65 years and above). Educational attainment was divided into elementary school or junior high school (≤9 years education), high school (10–12 years education), vocational college or junior college (13–15 years education), and university or graduate school (≥16 years education).

Mental–health status (non–specific psychological distress) was evaluated using the Kessler Psychological Distress (K6) Scale[12]. The validation of the Japanese version has been reported previously[13,14].

Socioeconomic variables. The socioeconomic variables included type of work and changes in work situation after the earthquake. A "Yes" answer to the latter question indicated that the person started a new job, became unemployed, changed jobs, or experienced an increase or decrease in income.

Disaster–related variables. The disaster–related variables consisted of current residence (in–

Table 1. Subject Characteristics by Sex and Age Groups.

		All residents (%)	All respondents (%)	Those who were analyzed (%)
Sex	Men	88,085 (48.8%)	32,301 (43.9%)	26,752 (44.0%)
	Women	92,519 (51.2%)	41,132 (55.9%)	33,952 (55.9%)
Age group	15–49 years	78,245 (43.3%)	25,027 (34.0%)	22,505 (37.1%)
	50–64 years	49,139 (27.2%)	21,340 (29.0%)	19,542 (32.2%)
	65 years and above	53,220 (29.5%)	27,066 (36.8%)	18,657 (30.7%)
Total		180,604	73,569	60,704

Among 180,604 persons who were mailed questionnaires in this survey, 73,569 responded (response rate were 40.7%). 60,704 were analyzed after exclusion criteria were applied.

side or outside Fukushima Prefecture), classification of house damage, as certified by the government (no damage, partial damage, partial collapse, partial but extensive collapse, and total collapse), living arrangement at the time of the survey (evacuation shelter, temporary housing, rental housing/apartment, relatives' home, and own home), experiencing the tsunami, experiencing the nuclear power plant accident (defined as hearing the explosion), and losing someone close because of the disaster.

Data analysis

The focus of the data analysis was the participants' answers to the survey (N = 60,704). First, we compared the PCL-S score with the median and the interquartile range. Using age- and sex-adjusted analysis of covariance (ANCOVA), log-transformed PCL-S scores were then compared by age, sex, years of education, history of mental illness, and municipality. Dunnett's procedure was used to test for significant differences between each category. Log-transformed PCL-S scores were also compared by socioeconomic- and disaster-related variables using ANCOVA adjusted for age and sex. The Dunnett's procedure was also used to test for significant differences between each category after ANCOVA. For age grouping, the analysis was conducted by first dividing the population into two groups (the labor force at 15–64 years old and the participants ≥65 years old), and then dividing the 15–64 age group into two groups at approximately the median age (50 years).

Multivariate-adjusted regression analyses were used to predict PCL-S point increases, based on the background variables of the respondents (sex [women = 0, men = 1], age [continuous variable], history of mental illness [No = 0, Yes = 1], educational status [elementary or junior high school = 0, high school = 1, vocational school or junior college = 2, university or graduate school = 3], residence [outside Fukushima Prefecture = 0, inside Fukushima Prefecture = 1]). We also conducted regression analysis to predict PCL-S scores by mental-health status, as measured by the K6 Scale (continuous variable). Three new variables were also created to examine the effect of multiple disaster stressors. The new variables were defined as the sum of (1) the trauma-exposure stressors, (2) the displacement stressors and (3) the socioeconomic stressors, all considered to be major stressors[15]. Thus, the trauma-exposure stressors consisted of experience of the tsunami (Yes/No), experience of the nuclear power plant accident (Yes/No), and the loss of someone close because of the disaster (Yes/No). The displacement stressors consisted of house damage (less than partial collapse/partial collapse and worse) and living arrangements (own house/other than own house). The socioeconomic stressors consisted of decreased income (Yes/No) and unemployment (Yes/No). These socioeconomic- and disaster-related factors were incorporated into the variables by referring to previous reports[13,15,16]. The regression analyses were also performed on the newly created variables. The interaction of trauma-exposure stressors, displacement stressors and socioeconomic stressors were estimated by analysis of variance using generalized linear model. Since the PCL-S cutoff score of 50 was used to determine PTSD prevalence, as recommended by Weathers *et al.*[17], a PCL-S score of ≥50 was defined as having provable PTSD, and the socioeconomic- and disaster-related factors related to provable PTSD were examined by multivariate-adjusted modified Poisson regression analysis.

Data were analyzed with SAS, version 9.4, statistical software package (SAS Institute, Cary, NC, USA). All probability values for the statistical tests were two-tailed, with p values <0.05 considered statistically significant.

Results

Figure 2 shows the distribution of PCL-S scores, which was positively skewed with a median of 29. When the PCL-S cut-off score of 50 was used as a threshold for provable PTSD, the total number of PCL-S high scorers (PCL-S ≥50) was 9,037 (14.1% of the number of surveys analyzed, i.e., the study sample). The demographic and background characteristics, socioeconomic and disaster-related variables, and the PCL-S scores (with the medians and the inter-quartile ranges) are presented in Tables 2 and 3.

Demographic and background characteristics

The median PCL-S score was higher among women compared to men (Table 2). The median PCL-S score was highest for the oldest group and lowest for the youngest group. People who had a history of mental illness were more likely to have a high PCL-S score.

Socioeconomic variables

Concerning type of employment, the median PCL-S score was lower among full-time employees than either part-time employees or the unemployed (including students and full-time homemakers) (Table 3). More than half of the participants experienced a change in work situation, and the median PCL-S score differed between these two groups. As for loss of employment, the median PCL-S score differed between the groups, as was the case of job change. Regarding increased income, the median of the high PCL-S scorers differed between the groups.

Disaster-related variables

More than 80% of the individuals reported living in Fukushima Prefecture. The median PCL-S score was higher for people living outside of Fukushima Prefecture (Table 3). The median PCL-S scores for those living in a shelter were higher than for the others. The median PCL-S scores were higher among people who had experienced the tsunami, the nuclear power plant accident, and lost someone close due to the disaster, compared with people who had not.

Regression analysis

As shown in Table 4, the PCL-S score was higher among women, older participants, and less-educated participants. The PCL-S score also was significantly related to a history of having a mental disorder. As compared to participants who had no previous mental illness, the estimated parameter (EP) for those who reported a prior mental disorder was 4.29 for the multivariate-adjusted model. The median PCL-S score was lower for participants living inside Fukushima Prefecture. As compared to the refugees living outside Fukushima, the EP for participants living inside it was −1.23 in the multivariate-adjusted model. Regarding mental-health status, a 1.81 increase in PCL-S score was associated with a one point increase in the K6 score in the multivariate-adjusted model.

Table 4 also shows that the PCL-S score in-

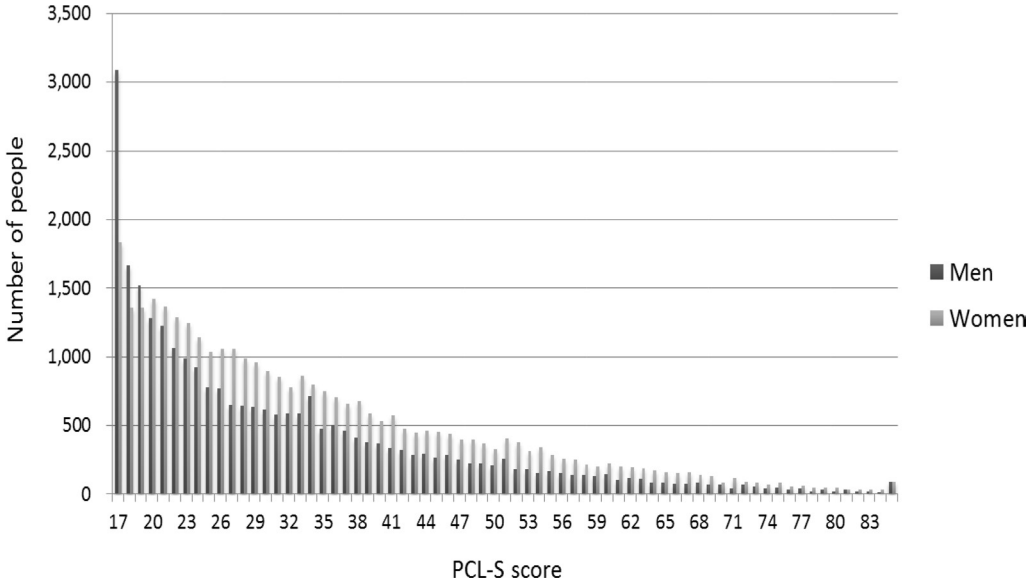

Figure 2. Distribution of PCL-S scores by age among men and women

Table 2. The Associations of Participants' Demographic and Background Characteristics with PTSD Severity.

	Total		PCL-S						
	Number	%	Mean	SD	Median	25th	75th	ANCOVA *p*-value	Post hoc *p*-value[a]
Sex									
Men	26,752	44.1	31.11	0.09	27	20	38	<0.001	
Women	33,952	56.0	34.51	0.08	30	22	43		
Age (years)									
15-49	22,505	37.1	31.42	0.10	27	21	38	<0.001	Reference
50-64	19,542	32.2	32.82	0.11	29	21	40		<0.001
≥65	18,657	30.7	35.14	0.11	31	22	45		<0.001
Education level									
Elementary or junior high school	14,743	24.3	34.72	0.12	31	21	44	<0.001	Reference
High school	30,179	49.7	32.90	0.09	29	21	41		<0.001
Vocational school or junior college	10,520	17.3	32.61	0.14	29	22	40		<0.001
University or graduate school	5,262	8.7	29.77	0.20	26	20	36		<0.001
History of mental illness									
Yes	2,924	4.8	46.80	0.27	46	32	32	<0.001	
No	57,786	95.2	32.32	0.06	28	21	39		
Residence area as of March 11, 2011									
Hirono	1,385	2.3	32.80	0.39	28	21	40	<0.001	
Naraha	2,322	3.8	34.53	0.30	31	22	43		
Tomioka	5,041	8.3	34.84	0.21	31	22	44		
Kawauchi	858	1.4	33.39	0.50	30	21	43		
Okuma	3,860	6.4	35.98	0.23	32	23	45		
Futaba	2,439	4.0	36.39	0.29	33	24	46		
Namie	7,817	12.9	35.30	0.16	32	23	44		
Katsurao	536	0.9	34.89	0.63	32	23	43		
Iitate	1,816	3.0	34.51	0.34	30	22	44		
Minamisouma	20,204	33.3	33.24	0.10	29	21	41		
Tamura	9,171	15.1	29.43	0.15	25	19	35		
Kawamata	4,386	7.2	27.97	0.22	24	19	33		
Part of Date[b]	869	1.4	29.00	0.49	24	19	34		

Note : 25th and 75th = 25th and 75th percentiles ; PCL-S = Posttraumatic Stress Disorder Checklist-Stressor Specific Version. [a]Dunnett's procedure was used for all analyses. [b]Restricted residential areas of Date City, as designated by the government

creased with increased numbers in trauma-exposure, displacement, and socioeconomic stressors. Each additional trauma-exposure stressor was associated with a 1.52 increase in the PCL-S score adjusted for age and sex. On the other hand, the number of displacement stressors and socioeconomic stressors were associated with increases in the PCL-S score by factors of 2.20 and 3.77, respectively. The interaction between these three stressors was significant (p value was 0.049).

Categorical analysis

Table 5 presents the adjusted odds ratios (ORs) and 95% CIs for the prevalence of provable PTSD (PCL-S ≥50) according to socioeconomic status and disaster-related variables. Psychological distress, unemployment, changing jobs, decreased income, house damage (total collapse), tsunami experience, nuclear power plant accident experience, and loss of someone close due to the disaster were associated with the prevalence of provable PTSD. Furthermore, the age- and sex-adjusted ORs (95% CIs) were 8.28 (7.94-8.63), 1.62 (1.54-1.69), 1.14 (1.03-1.27), 1.44 (1.34-1.48), 11.16 (8.28-15.04) (total collapse versus no damage), 1.73 (1.66-1.81), 2.10 (2.00-2.19), and 1.86 (1.77-1.94), respectively. After further adjusting for socioeconomic status and disaster-related variables, the ORs decreased. However, the significant associations remained, except for job changes.

Table 3. Socioeconomic and Disaster-Related Variables with PTSD Severity.

	Total		PCL-S						
	Number	%	Mean	SD	Median	25th	75th	ANCOVA *p*-value	Post hoc *p*-value[a]
Socioeconomic Variables									
Type of work									
Full-time	16,042	34.1	29.97	0.11	26	20	36	<0.001	Reference
Part-time	3,810	8.1	32.26	0.23	29	21	39		0.758
Unemployed[b]	27,225	57.9	33.78	0.08	30	22	42		<0.001
Changed work situation									
Yes	31,987	55.5	35.50	0.08	32	23	44	<0.001	
No	25,681	44.5	29.41	0.09	25	20	36		
Started a new job									
Yes	1,083	3.4	35.93	0.45	31	22	45	<0.001	
No	30,904	96.6	32.96	0.06	32	23	44		
Became unemployed									
Yes	12,917	40.4	36.87	0.13	33	24	46	<0.001	
No	19,070	59.6	31.98	0.07	22	43	9		
Changed jobs									
Yes	2,548	8.0	34.17	0.30	29	22	40	<0.001	
No	29,439	92.0	32.97	0.06	32	23	45		
Income has increased									
Yes	761	2.4	32.20	0.53	27	20	39	0.008	
No	31,226	97.6	33.03	0.06	32	23	44		
Income has decreased									
Yes	11,560	36.1	35.52	0.14	32	23	44	<0.001	
No	20,427	63.9	32.43	0.07	28	21	40		
Disaster-Related Variables									
Living place									
Inside Fukushima Prefecture	48,902	80.6	32.40	0.07	28	21	40	<0.001	
Outside Fukushima Prefecture	11,802	19.4	35.56	0.14	31	23	44		
House damage									
No	16,035	28.1	29.71	0.12	25	20	35	<0.001	Reference
Partial damage	31,977	56.1	33.21	0.08	29	21	41		<0.001
Partial collapse	4,296	7.5	37.17	0.22	34	24	47		<0.001
Partial but extensive collapse	1,593	2.8	39.37	0.36	36	25	51		<0.001
Total collapse	3,104	5.5	37.38	0.26	34	23	48		<0.001
Living arrangement at survey									
Evacuation shelter	539	1.1	35.53	0.62	33	22	48	<0.001	Reference
Temporary housing	5,580	11.5	34.79	0.19	31	23	44		0.2696
Rental housing/apartment	20,015	41.1	34.44	0.10	30	22	42		0.0011
Relative's home	2,207	4.5	33.94	0.30	30	22	42		0.0250
Own home	18,289	37.6	29.13	0.11	25	19	35		<.0001
Other	2,061	4.2	33.64	0.32	29	21	41.5		0.0006
Experience of tsunami									
Yes	12,306	20.3	37.14	0.13	34	24	47	<0.001	
No	48,398	79.7	31.97	0.07	28	21	39		
Experience of nuclear power plant accident[c]									
Yes	32,006	52.7	36.02	0.08	33	23	46	<0.001	
No	28,698	47.3	29.66	0.09	25	20	35		
Loss of someone close because of the disaster									
Yes	11,813	19.8	36.02	0.08	35	25	49	<0.001	
No	47,863	80.2	29.66	0.09	27	21	39		

Note : 25th and 75th = 25th and 75th percentiles ; PCL-S = Posttraumatic Stress Disorder Checklist-Stressor Specific Version. [a]Dunnett's procedure was used for all analyses. [b]Includes students and full-time homemakers. [c]Defined as having heard an explosion caused by the nuclear accident.

Table 4. Estimated Parameters and 95% Confidence Intervals of PCL-S Scores on the Regression Analysis.

		Adjusted for age and sex			Multivariate adjusted[c]		
		EP	95% CI		EP	95% CI	
Sex	Women 0 ; Men ; 1	−3.43[a]	−3.66	−3.20	−1.35	−1.52	−1.86
Age	Years	0.10[b]	0.10	0.11	0.10	0.09	0.10
Psychiatric history	No, 0 ; Yes, 1	14.24	13.71	14.77	4.29	3.91	4.68
Education level	Less than 10 years, 1 ; 10-12 years, 2 ; 13-15 years, 3 ; more than 15 years ; 4	−0.82	−0.96	−0.68	−0.63	−0.73	−0.53
Living place	Outside Fukushima, 0 ; Inside Fukushima, 1	−3.09	−3.58	−3.11	−1.23	−1.44	−1.02
Mental-health status (K6)	Score (0-24)	1.81	1.79	1.82	1.74	1.72	1.75
Number of trauma-exposure stressors	Number (0-3)	1.52	1.43	1.62	0.84	0.77	0.91
Number of displacement stressors	Number (0-2)	2.20	1.81	2.59	0.59	0.32	0.86
Number of socioeconomic stressors	Number (0-2)	3.77	3.57	3.97	1.29	1.15	1.43

Note : PCL-S = Posttraumatic Stress Disorder Checklist-Stressor Specific Version ; EP = Estimated parameter ; SD = Standard deviation ; CI = Confidence interval. R^2 of the multivariable regression analysis was 0.529.
[a]Age was adjusted. [b]Sex was adjusted. [c]Further adjusted for psychiatric history, education, living place, mental-health status, trauma-exposure stressors, displacement stressors, and socioeconomic stressors.

Discussion

This study aimed to document the restricted area residents' levels of PTSD symptoms and the relationships between these symptoms and demographic characteristics, socioeconomic status, and disaster-related variables. Participants were residents over 15 years of age who lived in the restricted area of Fukushima Prefecture. Among the evacuees in the study sample, 9,037 (14.1%) had severe PTSD symptoms (PCL-S ≥50) eighteen months after the earthquake. Previous reports have indicated that the prevalence of PTSD per year in Japan was approximately 0.4%[18]. Thus, a disproportionately large number of residents in the restricted area appeared to have experienced symptoms of PTSD following the disaster. As for demographic information, women, older adults, those with lower academic achievement, and those with a history of mental illness tended to have higher PTSD scores. In particular, participants who had a history of mental illness reported severe PTSD symptoms. Regarding the disaster-related stressors, people who experienced either the tsunami or nuclear power plant disaster, who lost family members or relatives, or who had serious house damage had higher PCL-S scores and had the risk of provable PTSD. Additionally, those who had to evacuate from Fukushima Prefecture or had to evacuate their houses for accommodations at a shelter or temporary housing showed severe PTSD symptoms. Regression analyses revealed that a greater quantum of exposure to disaster factors and socioeconomic status also contributed to significantly predicting PTSD. These findings have important implications regarding mental-health concerns that warrant special attention in order to support evacuees after large-scale disasters.

Many surveys have reported that PTSD is often observed after earthquake disasters[19,20]. After the 1995 Hanshin-Awaji Great Earthquake in Japan, many survivors exhibited PTSD symptoms[21,22]. In a survey conducted sixteen months after the earthquake, the prevalence of PTSD among office workers in the disaster area was 3.1%, while 10.1% of the workers were not diagnosed with PTSD but had some PTSD symptoms[23]. Another survey of 128 victims in the Hanshi-Awaji area (62 men and 66 women ; mean age, 32.1 years old) 3-4 months after the earthquake revealed that the prevalence of PTSD was 12.90% for men, 9.09% for women, and 10.94% for the total sample[24]. Although comparing the present study with these previous studies is difficult because of differences in the subjects and survey methods, a higher proportion of subjects in the present study appear to have PTSD symptoms, even after taking age into account.

Earthquake-induced tsunamis can also cause further damage to surrounding coastal areas[25]. An epidemiological study, conducted among 1,294 work-

Table 5. Odds ratios (OR) and 95% CIs for prevalence of provable PTSD among evacuees on modified Poisson regression analyses.

		Age- and sex-adjusted OR (95% CI)	Multivariate adjusted OR (95% CI) [a]
Sex	Men (reference)	1.00 (reference)	1.00 (reference)
	Women	1.96 (1.80–2.13)	1.46 (1.33–1.60)
Age	15–44 (reference)	1.00 (reference)	1.00 (reference)
	45–54	1.23 (1.07–1.42)	1.10 (0.94–1.28)
	55–64	1.37 (1.10–1.69)	1.15 (0.92–1.44)
	65–74	1.52 (1.14–2.02)	1.21 (0.89–1.63)
	≥75	1.68 (1.18–2.40)	1.27 (0.87–1.85)
Living place	Outside Fukushima (reference)	1.00 (reference)	1.00 (reference)
	Inside Fukushima	0.73 (0.69–0.76)	0.89 (0.85–0.94)
Psychological distress (K6 ≥13)	No (reference)	1.00 (reference)	1.00 (reference)
	Yes	8.28 (7.94–8.63)	7.11 (6.81–7.44)
Became unemployed	No (reference)	1.00 (reference)	1.00 (reference)
	Yes	1.62 (1.54–1.69)	1.17 (1.11–1.23)
Changed jobs	No (reference)	1.00 (reference)	1.00 (reference)
	Yes	1.14 (1.03–1.27)	1.02 (0.91–1.15)
Income has decreased	No (reference)	1.00 (reference)	1.00 (reference)
	Yes	1.44 (1.34–1.48)	1.16 (1.10–1.22)
House damage	No (reference)	1.00 (reference)	1.00 (reference)
	Partial damage	2.62 (2.33–2.96)	1.75 (1.55–1.97)
	Partial collapse	4.25 (3.56–5.09)	2.31 (1.93–2.77)
	Partial but extensive collapse	6.89 (5.43–8.75)	3.05 (2.40–3.89)
	Total collapse	11.16 (8.28–15.04)	4.04 (2.99–5.46)
Experience of tsunami	No (reference)	1.00 (reference)	1.00 (reference)
	Yes	1.73 (1.66–1.81)	1.21 (1.15–1.27)
Experience of nuclear power plant accident	No (reference)	1.00 (reference)	1.00 (reference)
	Yes	2.10 (2.00–2.19)	1.45 (1.38–1.52)
Loss of someone close because of the disaster	No (reference)	1.00 (reference)	1.00 (reference)
	Yes	1.86 (1.77–1.94)	1.25 (1.19–1.31)

[a]Adjusted for age, sex, living place, psychological distress, becoming unemployed, decreased income, house damage, experiencing the nuclear power plant accident, and loss of someone close.

ers (local municipality workers, $n = 610$; hospital medical workers, $n = 357$; firefighters, $n = 327$) in coastal areas of Miyagi Prefecture14 months after the Great East Japan Earthquake, found that the prevalence of probable PTSD among local municipality workers, hospital medical workers, and firefighters was 6.6%, 6.6%, and 1.6%, respectively[26]. According to that study, an increased risk of PTSD was associated with lack of rest in the municipal and medical workers, lack of communication with medical workers, and municipal workers' involvement in disaster-related work. These findings elucidate the importance of socioeconomic stressors as a risk factor of PTSD. Since most studies on PTSD after the Great East Japan Earthquake have focused on medical staff and workers[27], making simple comparisons with the results of the current study is difficult. However, a review reported that a higher proportion of residents and workers in the affected areas of Fukushima Prefecture had PTSD symptoms than in any of the previous studies, suggesting that the nuclear power plant accident may have had some effect[27].

After the nuclear power plant meltdown in Chernobyl, people near the accident site presented with long-term mental-health problems, including PTSD[28]. Bromet, Havenaar, and Guey[5] reported that technological disasters predict PTSD in approximately 15% to 75% of the survivors, depending on the gravity, severity, and level of threat from the disaster, the risk population, and the timing of the study. In the present survey, people who had experienced a nuclear disaster showed severe PTSD symptoms, and those evacuated due to the accident

experienced further deterioration of their symptoms.

Two meta-analyses by Brewin, Andrews, and Valentine[29] and Ozer, Best, Lipsey, and Weiss[30] were conducted to investigate the psychosocial risk factors of PTSD. Both studies found evidence that both trauma-related and post-trauma related factors, including socioeconomic factors, predicted PTSD. As noted, our results are consistent with Brewin's meta-analysis, showing that women, older and less educated people, and people with a psychiatric history exhibited more severe PTSD symptoms. A history of mental illness was a strong predictor of PTSD symptoms after the disaster. In Brewin's meta-analysis, trauma severity, lack of social support, and additional life stressors were somewhat better predictors of PTSD than pre-trauma factors. Consistent with this finding, our regression analyses showed that socioeconomic stressors tended to have higher estimated parameters on the PCL-S scores than disaster-related factors. Moreover, we could find significant interaction between these stressors, which indicates that these stressors interact for a further impact on PTSD. This study implied that it may be important to give refugees appropriate housing support or employment support as well as medical support for PTSD. We should intensively support those who have several traumatic events, women, older people, or those who have psychiatric history. We also need to research what types of living environments or employment arrangements we should provide for victims. Our regression analysis revealed that residence after the evacuations also affected the evacuees' symptoms, even in the multivariate adjusted model. Compared to the people living in Fukushima Prefecture, those living outside of it might not have received sufficient social support during the evacuation[31,32]. Moreover, they might have felt more anxious about radiation than those living in Fukushima, and therefore, might have decided to leave Fukushima. Further studies of perception of radiation risk should be conducted in the future. Although both of these meta-analyses show that previous trauma is an important risk factor for PTSD, this item was not included in our questionnaire, which is one limitation of our study.

PTSD is an anxiety problem that develops after extremely traumatic experiences, such as combat, crime, an accident, or natural disaster. This study showed that the nuclear power plant accident could also induce PTSD. The present study found that the PCL-S scores were significantly higher in Futaba Town, followed by Okuma, Namie, and Katsurao. These municipalities are located near the Fukushima Daiichi Nuclear Power Plant. This finding appears to be characteristic of Fukushima Prefecture after the nuclear accident because invisible and inaudible "information" about radioactive contamination may cause PTSD symptoms, in addition to real life experiences. In the case of Fukushima, the serious nature of the negative information brought on the stressors, which were fears of radiation exposure, or "radiophobia." The perception of radiation risk in Fukushima increased the psychological distress among evacuees[13]. Those who lived near the nuclear power plant might have had more PTSD symptoms or a longer delay in recovery due to the perceived stigma associated with radiation, their wounded pride among fellow residents within their hometowns, or their inability to gain a long-term perspective. Media coverage of disasters probably affected the public's perceptions by increasing fear and anxiety[33].

There are several strengths and limitations in this study. The strengths are that the sample size is large and the participants were drawn from the entire population of evacuees. Although this is a cross-sectional study, the presumption of causality is strong. As for the limitations, because the response rate was relatively low and the response rate varied according to sex and age groups, it is not clear that the respondents to the survey represented the population. However, when we further analyzed the associations of PCL scores with socioeconomic factors and disaster-related variables stratified by sex and age, the associations were essentially same regardless of sex and age. Furthermore, interviews have been used to compare the differences in subject characteristics between respondents and nonrespondents[34]. Thus, nonrespondents had a significantly higher proportion of psychological distress compared with the respondents. Therefore, the current study may have underestimated the proportion of individuals with PTSD. The other limitation is that PTSD symptoms were evaluated based on the individual questionnaires ; they were not based on interviews from experts.

In conclusion, this study revealed that, in addition to the earthquake and tsunami, the nuclear disaster and its consequent changes to evacuees' living arrangements might have increased the incidence of PTSD symptoms. In addition to PTSD risk, which has been found in previous studies, people's fear of radiation exposure and the need to coordinate improvements in social services are important areas of focus for mental-health support

professionals in Fukushima. In the future, observing trends in PTSD symptoms and examining factors that contribute to their improvement to maintain the mental health of residents in the evacuation zone of Fukushima Prefecture will be important.

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Conflicts of interests

We declare that we have no competing interests.

References

1. National Police Agency. Police Activities and Victims of the Great East Japan Earthquake on March 11, 2011. (in Japanese) https://www.npa.go.jp/news/other/earthquake2011/pdf/higaijokyo.pdf. [Accessed January 12, 2021].
2. The International Atomic Agency. Fukushima Nuclear Accident. https://www.iaea.org/newscenter/focus/fukushima. [Accessed January 12, 2021].
3. Bennett B, Repacholi M, Carr Z. Health effects of the Chernobyl accident and special health care programmes. Geneva : World Health Organization, 2006.
4. Bromet EJ. Mental health consequences of the Chernobyl disaster. J Radiol Prot, **32** : N71–75, 2012.
5. Bromet EJ, Havenaar JM, Guey LT. A 25 year retrospective review of the psychological consequences of the Chernobyl accident. Clin Oncol (Royal College of Radiologists), **23** : 297–305, 2011.
6. van Deventer E, Del Rosario Perez M, Tritscher A, Fukushima K, Carr Z. WHO's public health agenda in response to the Fukushima Daiichi nuclear accident. J Radiol Prot, **32** : N119–122, 2012.
7. Norris FH, Elrod CL. Psychosocial consequences of disaster : A review of past research. In Methods for disaster mental health research, eds. Fran H. Norris, Sandro Galea, Matthew J. Friedman, and Patricia J. Watson. New York, NY : Guilford Press, 20–44, 2006.
8. Matsuoka Y, Nishi D, Nakaya N, *et al.* Concern over radiation exposure and psychological distress among rescue workers following the Great East Japan Earthquake. BMC Public Health, **12** : 249, 2012.
9. Yasumura S, Hosoya M, Yamashita S, *et al.* Fukushima Health Management Survey Group. Study protocol for the Fukushima Health Management Survey. J Epidemiol, **22** : 375–383, 2012.
10. American Psychiatric Association. Diagnostic and statistical manual of mental disorders : DSM–IV–TR. Washington, DC : American Psychiatric Association, 2000.
11. Blanchard EB, Jones–Alexander J, Buckley TC, Forneris CA. Psychometric properties of the PTSD Checklist (PCL). Behav Res Ther, **34** : 669–673, 1996.
12. Kessler RC, Barker PR, Colpe LJ, *et al.* Screening for serious mental illness in the general population. Arch Gen Psychiatry, **60** : 184–189, 2003.
13. Suzuki Y, Yabe H, Yasumura S, *et al.* Mental Health Group of the Fukushima Health Management Survey. Psychological distress and the perception of radiation risks : the Fukushima Health Management Survey. Bull World Health Organ, **93** : 598–605, 2015.
14. Sakurai K, Nishi A, Kondo K, Yanagida K, Kawakami N. Screening performance of K6/K10 and other screening instruments for mood and anxiety disorders in Japan. Psychiatry Clin Neurosci, **65** : 434–441, 2011.
15. Holmes TH, Rahe RH. The Social Readjustment Rating Scale. J Psychosom Res, **11** : 213–218, 1967.
16. Yabe H, Suzuki Y, Mashiko H, *et al.* Psychological distress after the Great East Japan Earthquake and Fukushima Daiichi Nuclear Power Plant accident : Results of a Mental Health and Lifestyle survey through the Fukushima Health Management Survey in FY2011 and FY2012. Fukushima J Med Sci, **60** : 57–67, 2014.
17. Weathers FW, Litz BT, Herman DS, Huska JA, Keane TM. The PTSD Checklist (PCL) : Reliability, Validity, and Diagnostic Utility. Paper presented at the Annual Meeting of the International Society for Traumatic Stress Studies, San Antonio, TX, 1993.
18. Kawakami N, Takeshima T, Ono Y, *et al.* Twelve–month prevalence, severity, and treatment of com-

mon mental disorders in communities in Japan : Preliminary finding from the World Mental Health Japan Survey 2002-2003. Psychiatry Clin Neurosci, **59** : 441-452, 2005.
19. Zhang Z, Ran MS, Li YH, *et al.* Prevalence of post-traumatic stress disorder among adolescents after the Wenchuan earthquake in China. Psychological Med, **42** : 1687-1693, 2012.
20. Zhang Z, Shi Z, Wang L, Liu M. One year later : Mental health problems among survivors in hard-hit areas of the Wenchuan earthquake. Public Health, **125** : 293-300, 2011.
21. Kato H, Asukai N, Miyake Y, Minakawa K, Nishiyama A. Post-traumatic symptoms among younger and elderly evacuees in the early stages following the 1995 Hanshin-Awaji earthquake in Japan. Acta Psychiatrica Scandinavica, **93** : 477-481, 1996.
22. Fukuda S, Morimoto K, Mure K, Maruyama S. Life events and posttraumatic stress in Hanshin-Awaji earthquake victims. Environ Health Prev Med, **6** : 97-103, 2001.
23. Asukai N, Miyake Y. Contributing factors to post-disaster stress symptoms among office workers who survived the 1995 Hanshin-Awaji Earthquake. Seishin Igaku, **40** : 889-895, 1998 (in Japanese).
24. Sakano Y, Shimada H, Tsujiuchi T, *et al.* Psychosomatic problems after the Great Hanshin Earthquake in January 1995 (I) : Symptoms of posttraumatic stress disorders and psychological stress response. Jpn J Psychosom Med, **36** : 649-656, 1996 (in Japanese).
25. van Griensven F, Chakkraband ML, Thienkrua W, *et al.* Thailand Post-Tsunami Mental Health Study Group. Mental health problems among adults in tsunami-affected areas in southern Thailand. JAMA, **296** : 537-548, 2006.
26. Sakuma A, Takahashi Y, Ueda I, *et al.* Post-traumatic stress disorder and depression prevalence and associated risk factors among local disaster relief and reconstruction workers fourteen months after the Great East Japan Earthquake : A cross-sectional study. BMC Psychiatry, **15** : 58, 2015.
27. Matsumoto K, Sakuma A, Ueda I, Nagao A, Takahashi Y. Psychological trauma after the Great East Japan Earthquake. Psychiatry Clin Neurosci, **70** : 318-331, 2016.
28. Havenaar JM, Rumyantzeva GM, van den Brink W, *et al.* Long-term mental health effects of the Chernobyl disaster : An epidemiologic survey in two former Soviet regions. Am J Psychiatry, **154** : 1605-1607, 1997.
29. Brewin CR, Andrews B, Valentine JD. Meta-analysis of risk factors for posttraumatic stress disorder in trauma-exposed adults. J Consult Clin Psychol, **68** : 748-766, 2000.
30. Ozer EJ, Best SR, Lipsey TL, Weiss DS. Predictors of posttraumatic stress disorder and symptoms in adults : A meta-analysis. Psychol Bull, **129** : 52-73, 2003.
31. Cohen S, Wills T. Stress, social support, and the buffering hypothesis. Psychol Bull, **101** : 310-357, 1985.
32. Compas BE, Epping J. Stress and coping in children and families : Implications for children coping with disaster. In : C.F. Saylor, (Ed.). Children and disasters. New York : Plenum, 11-28, 1993.
33. Wray RJ, Becker SM, Henderson N, *et al.* Communicating with the public about emerging health threats : Lessons from the Pre-Event Message Development Project. Am J Public Health, **98** : 2214-2222, 2008.
34. Horikoshi N, Iwasa H, Yasumura S, Maeda M. The characteristics of non-respondents and respondents of a mental health survey among evacuees in a disaster : The Fukushima Health Management Survey. Fukushima J Med Sci, **63** : 152-159, 2017.