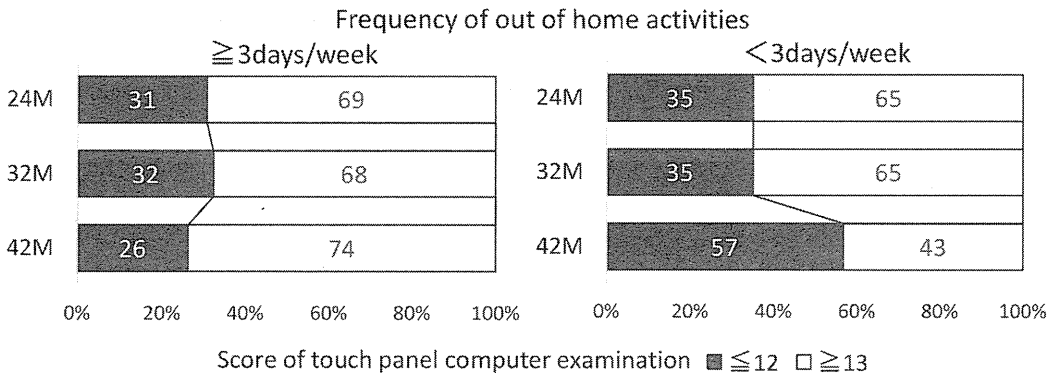

Fig 3. Changes in the ratio of people with normal cognitive function and those with declined cognitive function according to differences in the frequency of "out-of-home activities". White and black columns indicate the ratio of people with normal cognitive function (touch panel computer exam score of ≥13) and declined cognitive function (exam score of ≤12), respectively. Right and left panels indicate the results of the people with the frequency of "out-of-home activities" of ≥3 day/week and <3 day/week, respectively.

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(ii) loss of families, relatives, and friends, (iii) loss of their daily activities, and (iv) loss of communications with families and neighbors. Therefore, we are now planning to perform future studies to elucidate these issues. In addition, cerebral circulation could affect cognitive impairment because Omama et al. reported that the occurrence of cerebral infarction among elderly men was more than doubled after the disaster [14,15].

Sakuma et al. (2015) reported a high prevalence of post-traumatic stress disorder and depression in municipality and medical workers after the Great East Japan Earthquake [16]. The increase in the number of patients with seizures following the earthquake was also reported [17]. Our study indicates that K6 and AIS scores improved based on the comparison between the data at 24 and 42 months. The effects and influence of the disaster on the survivors is quite different and varied. We believe that subjects were under recovery after the disaster because the present study was conducted between 24 and 42 months after the earthquakes and tsunamis. Furthermore, the positive influence of care workers and volunteers to support the tsunami survivors in the improvement of depression and insomnia cannot be ignored.

In the multiple logistic regression analysis, frequency of "out-of-home activities" and "walking duration" were independently and inversely associated with an increase in the ratio of people with cognitive impairment. Kasper et al. (2015) reported that cognitive status in old age appears to impact on mobility and mood, rather than on involvement in out-of-home behavior connections [18]. They reported that the elderly people with AD and mild cognitive impairment (MCI) showed lower mood than cognitively healthy people. They also reported a strong positive link between mood and out-of-home behavior in patients with AD. Furthermore, the complexity of out-of-home behaviors among cognitively healthy, patients with MCI, and patients with AD was reported [19]. They concluded that cognitively demanding activities were significantly different between "MCI and cognitively healthy" and "AD and cognitively healthy" subjects. There are several studies reporting that physical activity or walking can protect against cognitive decline and dementia in the elderly people [20,21]. Karp et al. reported that a broad spectrum of activities seems to be more beneficial than to be engaged in only one type of activity to prevent dementia [22]. It is believed that "out-of-home activities" and "walking duration," which include physical movement and communication with others, should be beneficial in the prevention or delay of dementia symptoms.

In conclusion, the cognitive functions of elderly people living in temporary apartments are at risk. To prevent dementia or keep cognition stable, we recommend involvement in "out-of-

home activities" and "walking" as much as possible. As a result of our findings, we have now implemented some community programs based on "out-of-home activities" and "walking" at temporary apartments to prevent dementia and frailty.

Author Contributions

Conceived and designed the experiments: SO RK IT RN YT TT MK SM KI TK HA KF. Performed the experiments: AI SO NT TT SM TK KF. Analyzed the data: AI SO NT KF. Wrote the paper: AI SO KF.

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Longitudinal association between time-varying social isolation and psychological distress after the Great East Japan Earthquake

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ABSTRACT

Background: The association between social isolation and psychological distress among disaster survivors is inconclusive. In addition, because these previous studies were cross-sectional in design, the longitudinal association between time-varying social isolation and psychological distress was not clear. The present study examined the longitudinal association between social isolation and psychological distress after the Great East Japan Earthquake.

Methods: We analyzed longitudinal data for 959 adults who had responded to the self-report questionnaires about Lubben Social Network Scale-6 (LSNS-6) and K6 in both a community-based baseline survey (2011) and a follow-up survey (2014) after the disaster. Participants were categorized into four groups according to changes in the presence of social isolation (<12/30 of LSNS-6) at two time points (2011 and 2014): "remained socially isolated", "became not socially isolated", "remained not socially isolated", and "became socially isolated". We defined a K6 score of ≥10/24 as indicating the presence of psychological distress. We used multiple logistic regression analysis to estimate the adjusted odds ratios (ORs) and 95% confidence intervals (CIs) to indicate how the change in social isolation was related to changes in psychological distress over 3 years.

Results: Among the participants who had not shown psychological distress at the baseline, the rates of deterioration of psychological distress were significantly lower in participants who "became not socially isolated" (multivariate OR = 0.26, 95% CI = 0.08–0.70) and "remained not socially isolated" (multivariate OR = 0.49, 95% CI = 0.27–0.91), compared with participants who "remained socially isolated". Among the participants who had psychological distress at the baseline, the rate of improvement of psychological distress was significantly higher in participants who "remained not socially isolated" (multivariate OR = 2.61, 95% CI = 1.08–6.44).

Conclusion: The present findings suggest that prevention of social isolation may be an effective public health strategy for preventing psychological distress after a natural disaster.

1. Introduction

The Great East Japan Earthquake (GEJE) and associated tsunami struck the northeastern coast of Japan on March 11, 2011, leaving 18,550 persons dead or missing (Ishigaki et al., 2013). Previous studies have reported that the estimated prevalence of psychological distress after the GEJE was 42.6–48.0% (Niitsu et al., 2014; Sugimoto et al., 2015; Yokoyama et al., 2014), and that the prevalence of psychological distress among disaster survivors decreased steadily after the earthquake (Nakamura et al., 2014). However, there appears to have been considerable individual variation in psychological recovery, and the factors contributing to this variation have remained unclear.

Social isolation is associated with a higher risk of poor mental health, including depression (Cacioppo et al., 2010; Chou et al., 2011; Dorfman et al., 1995; Teo et al., 2013). Survivors from the

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GEJE were at high risk of social isolation due to the death of family or friends and evacuation from their home community. A previous study has demonstrated an association between social network disruption and psychological distress as a result of evacuation (Bland et al., 1997). Therefore, these environmental changes resulting from disasters create the potential for social isolation and a higher risk of psychological distress.

Previous studies have examined the association between social isolation and psychological distress in community-dwelling populations (Kuriyama et al., 2009; Phongsavan et al., 2006; Zhang and Chen, 2014), and reported that social isolation is significantly associated with an increased risk of psychological distress. However, this association among disaster survivors is inconclusive. Some studies have indicated that social isolation is significantly associated with psychological distress, whereas others have denied any such association (Koyama et al., 2014; Oyama et al., 2012; Sugimoto et al., 2015; Teramoto et al., 2015; Yokoyama et al., 2014). In addition, because these previous studies were cross-sectional in design, the longitudinal association between time-varying social isolation and psychological distress was not clear.

The present study examined the longitudinal association between social isolation and psychological distress after a major disaster. For this purpose, we followed up about 1000 survivors for more than 3 years after the GEJE.

2. Methods

2.1. Study design and participants

Baseline health examinations and questionnaire surveys were conducted from June to November, 2011. The aim of the survey was to evaluate mental and physical functional status. The study population comprised residents aged 18 years or older who were included in the Residential Registry for Ajishima, Ogatsu, and Oshika, Ishinomaki City, Miyagi Prefecture, and residents who were living in prefabricated temporary housing in Wakabayashi-ku, Sendai City, Miyagi Prefecture. These health surveys were repeated about every 6 months. The first three surveys involved health examinations and questionnaires, and thereafter questionnaire surveys were conducted four times. The study protocol was reviewed and approved by the Ethics Committee of Tohoku University Graduate School of Medicine.

We linked two datasets: one from questionnaire surveys conducted between June and November 2011, and another from questionnaire surveys conducted between June and August 2014. Of the 6501 study population (Ajishima; 460, Ogatsu; 1708, Oshika; 3357, and Wakabayashi-ku; 976), 1936 (29.8%) participated in the baseline health examination and questionnaire surveys (2011). Of the participants, 1180 responded to the follow-up survey (2014), and were thus eligible for analysis. We excluded 221 participants who had not entered any response to the questions about Lubben Social Network Scale-6 (LSNS-6), K6, economic status, alcohol consumption, smoking status, and self-rated health. Consequently, our final analysis included 959 participants.

2.2. Measurements

The questionnaire requested the following information from each participant: age, sex, economic status, history of disease, body weight and height, alcohol consumption, smoking status, self-rated health, sleeping condition, social network (LSNS-6) (Kurimoto et al., 2011; Lubben et al., 2006; Lubben and Gironda, 2003), psychological distress (K6) (Furukawa et al., 2003; Kessler et al., 2002, 2003), physical activity, and information about personal experience of the GEJE (evacuation, presence of post-traumatic stress disorder, change in job or income, degree of destruction of the dwelling, and dead or missing family members). In this study, alcohol consumption was divided into 3 categories (non-drinking, <2 *go*/day, and ≥2 *go*/day), where 22.8 g of alcohol amounts to 1 *go*, a traditional unit of *sake* (180 ml), which also approximates to two glasses of wine (200 ml) or beer (500 ml) in terms of alcohol content.

The LSNS-6 was used as an indicator of social isolation (Lubben et al., 2006; Lubben and Gironda, 2003). The reliability and validity of the Japanese version of the LSNS-6 have been confirmed (Kurimoto et al., 2011). This measure is constructed from a set of 3 questions that evaluate family ties and a comparable set of 3 questions that evaluate friendship ties. The LSNS-6 includes the following six items: [1] "How many relatives do you see or hear from at least once a month?" [2] "How many relatives do you feel close to such that you could call on them for help?" [3] "How many relatives do you feel at ease with that you can talk about private matters?" [4] "How many of your friends do you see or hear from at least once a month?" [5] "How many friends do you feel close to such that you could call on them for help?" or [6] "How many friends do you feel at ease with that you can talk about private matters?" The possible responses and their scores were: "none" (0 point), "one" (1 point), "two" (2 points), "three or four" (3 points), "five to eight" (4 points), and "nine or more" (5 points). The total scores ranged from 0 to 30. As suggested by Lubben et al., we classified individuals with scores of <12/30 points as being socially isolated. The participants were then classified into the following 4 groups: "remained socially isolated" (socially isolated in both 2011 and 2014), "became not socially isolated" (socially isolated in 2011 and not socially isolated in 2014), "remained not socially isolated" (not socially isolated in both 2011 and 2014), and "became socially isolated" (not socially isolated in 2011 and socially isolated in 2014).

The K6 was used to assess psychological distress (Kessler et al., 2002, 2003). The Japanese version of the K6 has been validated previously (Furukawa et al., 2003). The K6 consists of six questions about how often an individual has felt the following in the last month: [1] nervous, [2] hopeless, [3] restless or fidgety, [4] so sad that nothing could cheer you up, [5] everything is an effort, or [6] worthless. The possible responses and their scores were as follows: "all of the time" (4 points), "most of the time" (3 points), "some of the time" (2 points), "little of the time" (1 point), and "none of the time" (0 point). The total K6 score for the six questions was 24 (0 indicating no psychological distress and 24 indicating severe psychological distress). In a previous study, a cut-off point of ≥10/24 has been used to screen for psychological distress (Suzuki et al., 2014). We classified respondents with scores of ≥10/24 as having a higher degree of psychological distress.

2.3. Statistical analyses

First, to test whether the changes in social isolation was associated with changes in psychological distress (K6 in 2014 minus K6 in 2011), we used a linear mixed model with a random intercept including the study region (Ajishima, Ogatsu, Oshika, or Wakabayashi-ku). We also stratified the participants by their degree of psychological distress at the baseline (those with no psychological distress; those with psychological distress).

Second, we conducted cross-sectional analysis to evaluate the association between social isolation and psychological distress at the baseline (2011). The dependent variable was psychological distress. The independent variable was social isolation (socially isolated; not socially isolated). Multiple logistic regression analysis was used to calculate the odds ratios (ORs) and 95% confidence intervals (CIs) for higher psychological distress according to the categories for social isolation (socially isolated; not socially isolated).

Third, we conducted longitudinal analyses to evaluate the association between time-varying social isolation and psychological distress after the GEJE. We stratified the participants by their degree of psychological distress at the baseline (those with no psychological distress; those with psychological distress). The dependent variables were the change in psychological distress (deterioration; improvement). The independent variables were the change in social isolation ("remained socially isolated"; "became not socially isolated"; "remained not socially isolated"; and "became socially isolated"). We then used multiple logistic regression analysis to estimate the adjusted ORs and 95% CIs to indicate how the change in social isolation was related to changes in psychological distress over 3 years.

We considered the following variables to be potential confounders: age in years (18–49, 50–64, 65–74, or ≥75), sex (man or woman), economic status [normal or severe (very severe, severe, or slightly severe)], alcohol consumption (non-drinking, <2 go/day, or ≥2 go/day), smoking status (non-smoking, or currently smoking), self-rated health [good (very good or good) or poor (poor or bad)], degree of dwelling destruction [small-scale damage (minimal or no damage), large-scale damage (largely or totally destroyed), or unknown], dead or missing family members (no, yes, or unknown), and study region (Ajishima, Ogatsu, Oshika, or Wakabayashi-ku). All statistical analyses were performed using SAS version 9.4 (SAS Inc., Cary, NC, USA). Differences at $p < 0.05$ were considered to be statistically significant.

3. Results

3.1. Distribution of social isolation and psychological distress

Our analysis of changes in social isolation between 2011 and 2014 revealed that 64.0% of participants remained not socially isolated, 11.1% became socially isolated, 10.0% became not socially isolated, and 14.9% remained socially isolated (Table 1).

The point prevalence of psychological distress did not differ significantly between 2011 and 2014 (17.0% and 15.0%, p = 0.09). With regard to the change in prevalence of psychological distress during the same period, 10.6% of the participants showed improvement, and 8.7% showed deterioration (Table 1).

3.2. Baseline characteristics according to social isolation and psychological distress

As shown in Table 2, participants who "became not socially isolated" were older, less likely to have poor self-rated health, large-scale damage to their dwelling, and dead or missing family members compared with participants who "remained socially isolated". Also, as compared with participants who "remained socially isolated", participants who "remained not socially isolated" were older, less likely to have severe economic status, to be current smokers, to have poor self-rated health, and large-scale damage to their dwelling.

Participants who had "high psychological distress" were more likely to have severe economic status, poor self-rated health, and dead or missing family members in comparison with participants who had "low psychological distress" (Supplementary Table 1).

3.3. Longitudinal analysis: the effect of change in psychological distress on change in social isolation

There were significant reductions in the K6 scores of participants who "became not socially isolated" ($\beta = -1.5$, standard error = 0.6, p = 0.01) and participants who "remained not socially isolated" ($\beta = -1.1$, standard error = 0.5, p = 0.02), comparison with participants who "remained socially isolated" (Table 3).

In addition, we stratified the participants by their degree of psychological distress at the baseline. Among participants without psychological distress at the baseline, there were significant reductions in the K6 scores of participants who "became not socially isolated" ($\beta = -2.0$, standard error = 0.6, $p < 0.01$) and participants who "remained not socially isolated" ($\beta = -1.3$, standard error = 0.5, p = 0.01), in comparison with participants who "remained socially isolated". Among participants with psychological distress at the baseline, there were significant reductions in the K6 scores of participants who "remained not socially isolated" ($\beta = -2.1$, standard error = 0.8, p = 0.02), in comparison with participants who "remained socially isolated" (Supplementary Table 2).

3.4. Cross-sectional analysis: social isolation and psychological distress

As shown in Table 4, there was no statistically significant association between social isolation and psychological distress (multivariate OR = 0.84, 95% CI = 0.56–1.28, p = 0.41).

3.5. Longitudinal analysis: deterioration of psychological distress among participants without psychological distress at the baseline

As shown in Table 5, significantly lower rates of psychological distress deterioration were observed in participants who "became not socially isolated" (multivariate OR = 0.26, 95% CI = 0.08–0.70, p = 0.01) and participants who "remained not socially isolated" (multivariate OR = 0.49, 95% CI = 0.27–0.91, p = 0.02), compared with participants who "remained socially isolated".

Table 1
Categories of change in social isolation and psychological distress.

Social isolation change		2014	
		No social isolation	Social isolation
2011	No social isolation	Remained not socially isolated n = 614 (64.0%)	Became socially isolated n = 106 (11.1%)
	Social isolation	Became not socially isolated n = 96 (10.0%)	Remained socially isolated n = 143 (14.9%)
Psychological distress change		**2014**	
		Low psychological distress	High psychological distress
2011	Low psychological distress	Remained low distress n = 713 (74.4%)	Deterioration n = 83 (8.7%)
	High psychological distress	Improvement n = 102 (10.6%)	Remained high distress n = 61 (6.4%)

Table 2
Baseline characteristics according to social isolation.

Characteristic	Total	Social isolation change (2011–2014)			
		Remained socially isolated	Became not socially isolated	Remained not socially isolated	Became socially isolated
No. of subjects	959	143	96	614	106
Age in 2011 in years (%)					
18–49	19.7	24.5	19.8	17.3	27.4
50–64	31.3	38.5	31.3	28.3	38.7
65–74	30.1	25.2	28.1	33.2	20.8
≥75	18.9	11.9	20.8	21.2	13.2
Sex (%)					
Man	44.5	47.6	51.0	43.2	42.5
Woman	55.5	52.5	49.0	56.8	57.6
Economic status (%)					
Normal	39.7	36.4	32.3	42.2	36.8
Severe	60.3	63.6	67.7	57.8	63.2
Alcohol consumption (%)					
Non-drinking	64.4	64.3	65.6	64.8	61.3
Current, <2 go/day	20.5	21.7	21.9	19.7	22.6
Current, ≥2 go/day	15.0	14.0	12.5	15.5	16.0
Smoking status (%)					
Non-smoking	80.5	76.9	75.0	82.3	80.2
Currently smoking	19.5	23.1	25.0	17.8	19.8
Self-rated health (%)					
Good health	82.8	76.2	82.3	84.9	80.2
Poor health	17.2	23.8	17.7	15.2	19.8
Degree of dwelling destruction (%)					
Small-scale damage	24.9	18.2	22.9	28.7	14.2
Large-scale damage	60.3	67.1	55.2	58.1	67.9
Unknown	14.8	14.7	21.9	13.2	17.9
Dead or missing family members (%)					
No	59.9	59.4	55.2	60.9	58.5
Yes	24.9	25.2	20.8	25.7	23.6
Unknown	15.2	15.4	24.0	13.4	17.9

Table 3
The effect of change in psychological distress on change in social isolation.

Psychological distress (K6)	Total	Social isolation change (2011–2014)			
		Remained socially isolated	Became not socially isolated	Remained not socially isolated	Became socially isolated
No. of subjects	959	143	96	614	106
K6 (2011), mean ± SD	5.3 ± 4.7	6.7 ± 5.0	5.0 ± 4.3	4.7 ± 4.5	6.6 ± 5.1
K6 (2014), mean ± SD	4.4 ± 4.9	6.5 ± 5.5	3.5 ± 4.1	3.6 ± 4.3	6.7 ± 6.0
Change in K6 (2014–2011), mean ± SD	−0.9 ± 4.8	−0.2 ± 5.4	−1.5 ± 4.1	−1.1 ± 4.6	0.1 ± 5.1
β ± SE		Ref.	−1.5 ± 0.6	−1.1 ± 0.5	0.2 ± 0.7
p value		–	0.01	0.02	0.74

Abbreviation: SD = standard deviation, SE = standard error.
The participants were classified into the following 4 groups: "remained socially isolated" (socially isolated in both 2011 and 2014), "became not socially isolated" (socially isolated in 2011 and not socially isolated in 2014), "remained not socially isolated" (not socially isolated in both 2011 and 2014), and "became socially isolated" (not socially isolated in 2011 and socially isolated in 2014).
Linear mixed effects regression models were adjusted for age in years (18–49, 50–64, 65–74, or ≥75), sex (man or woman), economic status (normal or severe), alcohol consumption (non-drinking, <2 go/day, or ≥2 go/day), smoking status (non-smoking or currently smoking), and self-rated health (good or poor), degree of dwelling destruction (small-scale damage, large-scale damage, or unknown), dead or missing family members (no, yes, or unknown).
A random intercept was included for the clustering of study region (Ajishima, Ogatsu, Oshika, or Wakabayashi-ku).

Table 4
Cross-sectional analysis: multivariate odds ratio (OR) and 95% confidence interval (CI) of higher psychological distress according to social isolation.

	Social isolation (2011)	
	Socially isolated	Not socially isolated
No. of subjects	239	720
No. of subjects with high psychological distress	50	113
Multivariate adjusted OR (95% CI)	1.00 (Ref.)	0.84 (0.56–1.28)
p value	–	0.41

The outcomes were higher psychological distress in 2011.
Multivariate odds ratios were adjusted for age in years (18–49, 50–64, 65–74, or ≥75), sex (man or woman), economic status (normal or severe), alcohol consumption (non-drinking, <2 go/day, or ≥2 go/day), smoking status (non-smoking or currently smoking), self-rated health (good or poor), degree of dwelling destruction (small-scale damage, large-scale damage, or unknown), dead or missing family members (no, yes, or unknown), and study region (Ajishima, Ogatsu, Oshika, or Wakabayashi-ku).

Table 5
Longitudinal analysis: multivariate odds ratio (OR) and 95% confidence interval (CI) of psychological distress deterioration according to change in social isolation among participants who did not have psychological distress at the baseline.

	Social isolation change (2011–2014)			
	Remained socially isolated	Became not socially isolated	Remained not socially isolated	Became socially isolated
Low psychological distress in 2011				
No. of subjects	106	83	526	81
No. of subjects with deterioration	19	5	48	11
Multivariate adjusted OR (95% CI)	1.00 (Ref.)	0.26 (0.08–0.70)	0.49 (0.27–0.91)	0.69 (0.29–1.57)
p value	–	0.01	0.02	0.39

The outcomes were psychological distress deterioration (high psychological distress in 2014).
The participants were classified into the following 4 groups: "remained socially isolated" (socially isolated in both 2011 and 2014), "became not socially isolated" (socially isolated in 2011 and not socially isolated in 2014), "remained not socially isolated" (not socially isolated in both 2011 and 2014), and "became socially isolated" (not socially isolated in 2011 and socially isolated in 2014).
Multivariate odds ratios were adjusted for age in years (18–49, 50–64, 65–74, or ≥75), sex (man or woman), economic status (normal or severe), alcohol consumption (non-drinking, <2 *go*/day, or ≥2 *go*/day), smoking status (non-smoking or currently smoking), self-rated health (good or poor), degree of dwelling destruction (small-scale damage, large-scale damage, or unknown), dead or missing family members (no, yes, or unknown), and study region (Ajishima, Ogatsu, Oshika, or Wakabayashi-ku).

3.6. Longitudinal analysis: improvement of psychological distress among participants with psychological distress at the baseline

As shown in Table 6, a significantly higher rate of psychological distress improvement was observed in participants who "remained not socially isolated" (multivariate OR = 2.61, 95% CI = 1.08–6.44, p = 0.03), compared with participants who "remained socially isolated".

4. Discussion

In the present study, we examined the longitudinal association between social isolation and psychological distress after the GEJE. Although the point prevalence of psychological distress did not differ between 2011 and 2014 (17.0% and 15.0%), we observed a difference in this change by observing changes in social isolation. Rates of deterioration of psychological distress were significantly lower in participants who "became not socially isolated" and "remained not socially isolated", compared with participants who "remained socially isolated". The rate of improvement of psychological distress was significantly higher in participants who "remained not socially isolated". Because all previous studies were cross-sectional in design (Koyama et al., 2014; Oyama et al., 2012; Sugimoto et al., 2015; Teramoto et al., 2015; Yokoyama et al., 2014), our present study is the first study to have investigated the longitudinal association.

Nakamura et al. examined changes in the prevalence of psychological distress using the General Health Questionnaire-12, and found that the overall prevalence decreased from 51.0% to 30.1% over 3 years (Nakamura et al., 2014). We found that the change in prevalence of psychological distress after changing the cut-off point (K6 score ≥5) was 50.6% (2011) and 38.6% (2014), respectively. Because our findings were consistent with the previous report, they might be applicable to other disaster victims.

Our data for social isolation showed that 11.1% of participants changed from being not socially isolated to being socially isolated, and that 10.0% changed from being socially isolated to not being socially isolated. Some disaster survivors were required to relocate to temporary housing, and then from temporary housing to disaster restoration housing, and thus their living environment changed over several years. A previous study has also demonstrated an association between social network disruption and psychological distress following evacuation (Bland et al., 1997). Because the proportion of social isolation was higher in the victims included in our study than in community residents (Kurimoto et al., 2011), changes in environmental factors due to the earthquake and tsunami might have affected the changes in social networks. In addition, previous studies have reported that depression is caused by social isolation (Cacioppo et al., 2010; Teo et al., 2013). Therefore, changes in social isolation caused by the GEJE might have changes the degree of psychological distress.

Because previous studies have used other cut-off points to screen for psychological distress (Koyama et al., 2014; Sugimoto et al., 2015; Yokoyama et al., 2014), we repeated all our analyses after classifying respondents with K6 scores of ≥13/24 as having higher psychological distress. As a result of this analysis, the point estimations were essentially the same as in Tables 5 and 6. Among the participants who did not have psychological distress in 2011,

Table 6
Longitudinal analysis: multivariate odds ratio (OR) and 95% confidence interval (CI) of psychological distress improvement according to change in social isolation among participants who had psychological distress at the baseline.

	Social isolation change (2011–2014)			
	Remained socially isolated	Became not socially isolated	Remained not socially isolated	Became socially isolated
High psychological distress in 2011				
No. of subjects	37	13	88	25
No. of subjects with improvement	18	11	64	9
Multivariate adjusted OR (95% CI)	1.00 (Ref.)	4.20 (0.78–33.78)	2.61 (1.08–6.44)	0.46 (0.14–1.44)
p value	–	0.12	0.03	0.19

The outcomes were psychological distress improvement (low psychological distress in 2014).
The participants were classified into the following 4 groups: "remained socially isolated" (socially isolated in both 2011 and 2014), "became not socially isolated" (socially isolated in 2011 and not socially isolated in 2014), "remained not socially isolated" (not socially isolated in both 2011 and 2014), and "became socially isolated" (not socially isolated in 2011 and socially isolated in 2014).
Multivariate odds ratios were adjusted for age in years (18–49, 50–64, 65–74, or ≥75), sex (man or woman), economic status (normal or severe), alcohol consumption (non-drinking, <2 *go*/day, or ≥2 *go*/day), smoking status (non-smoking or currently smoking), self-rated health (good or poor), degree of dwelling destruction (small-scale damage, large-scale damage, or unknown), dead or missing family members (no, yes, or unknown), and study region (Ajishima, Ogatsu, Oshika, or Wakabayashi-ku).

the multivariate OR for higher psychological distress was 0.21 among participants who "became not socially isolated", and 0.33 among participants who "remained not socially isolated", as compared to participants who "remained socially isolated". Among the participants who had psychological distress in 2011, the multivariate OR for lower psychological distress was 3.58 among participants who "became not socially isolated", and 2.39 among participants who "remained not socially isolated". In addition, although a sensitivity analysis was performed using a multiple imputation procedure for LSNS-6 and K6 in the follow-up survey for participants who dropped out, the results obtained using multiple imputation were consistent with our main results.

The present study had some limitations. First, our sample size of 959 was not sufficiently large to obtain adequate statistical power for examining our hypotheses. For example, the point estimates were lower for participants who were "not socially isolated" in Table 4 (multivariate OR = 0.84, p = 0.41) and higher for participants who "became not socially isolated" in Table 6 (multivariate OR = 4.20, p = 0.12), compared with participants who "remained socially isolated". However, because there was no statistically significant association between social isolation and psychological distress, a further study with a larger sample size will be needed. Second, the valid response rate (49.5%, 959 participants) was not high among the study population of 1936, and thus the study may have been biased. However, as compared with the characteristics of participants who were included in this study (959 participants), participants who did not respond to the questionnaire in 2014 (977 participants) tended to be older. Among our study participants, the strength of the longitudinal association between social isolation and psychological distress was similar in both younger and older participants. Third, because our study included no control group comprising persons who were not affected by the disaster, we did not correctly interpret any changes in psychological distress caused by the disaster.

5. Conclusion

Among the people who lived in the disaster area affected by the GEJE, being free from social isolation was associated with improvement of psychological distress. The present findings suggest that prevention of social isolation may be an effective public health strategy for preventing psychological distress after a natural disaster.

Acknowledgments

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.socscimed.2016.01.037.

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Life and Mental Health of Medical Students after the Great East Japan Earthquake

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Students of the Tohoku University School of Medicine experienced the Great East Japan Earthquake on March 11, 2011. We conducted a series of surveys to examine the relationships among their experiences and activities on the day of the earthquake, their physical, mental, and economic problems following the disaster, and how their problems changed over time. The initial survey was performed in April 2011, with three follow-up surveys in July 2011, February 2012, and April 2013. The initial survey focused on students' experiences and living conditions during the disaster, which contained questions on their locations and circumstances, family circumstances, lives after the earthquake, voluntary works, physical or mental health problems, and desire for counseling. The follow-up surveys included new items regarding their circumstances, changes in their health problems, and their desire for economic assistance. Students who answered the first survey to the 4th one, with response rates in the following bracket, were as follows: 472 (28.0%), 640 (29.9%), 681 (36.0%), and 678 (39.0%), respectively. Six months after the earthquake, about 20% having experienced physical and/or mental problems. Although there was a trend toward a reduction in suffering and health problems over time, some students' conditions remained unchanged or worsened. It is notable that students who had participated in voluntary activities, despite their own suffering of harm and distress, were identified as the group that required the closest attention. Our present results can be applied to appropriate supports for students in future large-scale disasters.

Keywords: data mining; disaster; education; tsunami; volunteers
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Introduction

The "2011 off the Pacific Coast of Tohoku Earthquake," also known as the Great East Japan Earthquake, occurred at 14:46 on March 11, 2011, with the epicenter off the Sanriku coast, approximately 70 km east of Sendai in Miyagi Prefecture, where Tohoku University is located. Seismic intensities of the magnitude 9.0 earthquake were recorded at 7 in Kurihara City in the same prefecture and slightly under 6 at Tohoku University (Japan Meteorological Agency 2013).

The disaster inflicted substantial damage across a broad area from Tohoku to the Kanto region, as the earthquake also caused a large tsunami, liquefaction, and land subsidence. In addition, the earthquake and tsunamis caused the Fukushima Daiichi nuclear disaster in the neighboring prefecture of Fukushima. Two years after the disaster (at the time of the writing of this article on September 9, 2013), 18,703, 2,674, and 6,220 people were recorded as deceased, missing, and injured, respectively, as a result of the Great East Japan Earthquake (Shibahara 2011). In addition, many victims were forced to live in evacuation shelters, with the total number of evacuees (as of January 9, 2015) from Miyagi and the neighboring prefectures of Iwate and Fukushima recorded at 61,355 (Fire and Disaster Management Agency 2013; National Police Agency 2015).

When the earthquake struck, Tohoku University School of Medicine students of all departments, with the exception of third-year medical students, were absent due to the spring break; therefore, when they returned to begin the new term, it was critical to understand how they had been affected by the disaster, and whether they had experienced physical or psychological difficulties. For students in the graduate school, understanding these issues was important in the context of whether they would be able to continue their studies. Students from the Tohoku region com-

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prise a large proportion of the university's student body, and considering the possibility that family finances were devastated, data were required to understand the impact of the disaster on each student. Moreover, given the reports in the literature regarding various experiences that can result in trauma for victims of this type of large-scale disaster, we believed that a considerable number of students would have been exposed to traumatic situations (Kin and Onuma 2012; National Center of Neurology and Psychology 2012).

It is therefore essential to survey the students' experiences of the disaster quickly and act without delay to improve their situations via interventions such as mental health care and economic assistance. Furthermore, given the inevitability that resolution of the many problems arising from a disaster of this scale would occur over a long period, we implemented a series of surveys over time.

The purpose of this research was to investigate the aftermath and devastating effects of the Great East Japan Earthquake, as follows: 1) the physical, mental, and economic problems that arose for students; 2) physical and mental problems associated with students' experiences and activities at the time of the disaster; and 3) the long-term impact of the disaster on the students and how this changed over time. Furthermore, we examined the survey results to determine the types of response that should be considered by educational and other institutions when large-scale disasters occur in the future.

In addition, when students requested assistance during the implementation of the surveys, the survey sponsors provided either direct assistance or resources, such as counseling services, scholarships, or economic assistance, to enable students to address their problems independently.

Methods

Survey participants

In Japan, undergraduate systems for students who will participate in medical care in the future are as follows. (1) Medical doctors' license can be obtained after the state examination, and only those who are authorized such as graduation of the 6-year course of education in medical schools can take this state examination. "The Department of Medicine" in this study corresponds to such medical school. (2) "The Department of Health Sciences" in our university has a 4-year program, and students who wish to be nurses, radiation technologists, or clinical laboratory technologists are studying to take a state examination.

At our graduate school, a wide variety of students are studying including medical doctors (MDs) and others, but most of the graduate students are MDs.

We implemented a series of surveys involving undergraduate and graduate students from the Tohoku University School of Medicine between 2011 and 2013. Second- to fourth-year health sciences students were not included in Survey 1, as we were unable to obtain the agreement of the board of the Department of Health Sciences. After 2012, data from new students were excluded because they completed a different questionnaire from that completed by the other students. In addition, data from those who graduated from our medical school in each year were also excluded in this study.

Survey methodology and content

We implemented four surveys in April 2011, July 2011, February 2012, and April 2013 to examine the students' experiences of the disaster. The survey questionnaire items included: 1) consent to participate in the survey; 2) year of study, school ID, and name; 3) location at the time of the disaster; 4) experiences during the disaster; 5) experiences of those close to them (e.g., family members); 6) post-disaster changes in experience; 7) post-disaster living situation; 8) participation in voluntary activities (yes/no); 9) voluntary activity location, content, and duration; 10) physical distress (yes/no); 11) mental distress (yes/no); 12) changes in physical/mental health since the disaster; 13) desire for counseling (yes/no); and 14) other (free response). It was hypothesized that, as time passed after the disaster, the students' experiences would change; therefore, the four survey questionnaires were created using different combinations of these items, as appropriate for the timing of each survey. Respondents were permitted to leave questions unanswered, and we stated clearly that students who did not consent to survey participation would remain entitled to counseling assistance for any problems experienced.

The questionnaires were distributed at orientation events for new academic terms and in other situations in which students were assembled, including classes. If graduate students were absent from the campus and could not receive the questionnaire directly, we requested that the office of the department to which the student belonged forward it to the student via mail. An envelope was provided for confidentiality, and a collection box was permanently located in the medical department office to ensure that the envelopes containing the questionnaires could be returned at any time.

Survey sponsors

The Tohoku University School of Medicine Office of Medical Education drew the draft, and the Medical Department's Student Welfare Committee brushed up to finalize the questionnaires. The tabulation and analysis of the results were performed by the authors.

Analysis methodology for the survey results

The data were analyzed using contingency table tests for independence (chi-square tests), and residual analyses were performed to determine the differences between cells in contingency tables of 3 or more data categories. The p values for the residual analyses (Haberman, 1973) were: $p < 0.01$ for $r > 2.58$ and $p < 0.05$ for $r > 1.96$. IBM SPSS® Statistics 21.0 was used to perform the chi-square tests and residual analyses. In addition, the relationships between the responses to the question "How did people close to you fare in the disaster?" ("Someone was harmed," "Home and property were damaged," and "Domestic finances became difficult") and the survey items "I have physical distress," "I have mental distress," and "I participated in voluntary activities" (yes/no responses for all 6 items) were analyzed using covariance structure analysis (Kano and Miura 2002; Toyoda 2007) and data mining (cluster analysis and association analysis) (Agrawal et al. 1993; Yamaguchi et al. 2004).

Covariance structure analysis

We used covariance structure analysis to analyze the relationships between factors underlying the multivariate data measures. We performed an exploratory factor analysis with covariance structure analysis using a model configured with latent variables and the following 6 items: "Someone was harmed," "Home and property were

damaged," "Domestic finances became difficult," "I experience physical distress," "I experience mental distress," and "I participated in voluntary activities." Exploratory factor analysis was performed using a Markov chain Monte Carlo (MCMC) method with IBM SPSS® Amos 21.0 software.

Cluster analysis

Cluster analysis is a classification method for grouping data with similar characteristics within a sample consisting of several variables. In this study, it was used to divide the sample into groups (clusters) to understand the results of the other analyses more clearly via examination of group characteristics. There is a disadvantage to cluster analysis, in that the researcher is able to determine the number of clusters at will, which can lead to arbitrary results. However, we adopted a method to prevent this—namely, using the two-step cluster analysis procedure, which automatically determines the most suitable number of clusters. We also used the Akaike (AIC) and Bayesian information criteria (BIC) in the algorithm. IBM SPSS® Statistics 21.0 was used to perform the two-step cluster analysis.

Association analysis

Association analysis is a type of data mining that enables the effective generation of rules relevant to the occurrence of B (Consequent) given the occurrence of A (Antecedents) in a database, by finding database "itemsets" (item combinations) of value from an infinite number of itemsets. The strength of the rules is evaluated according to measured support, confidence, and lift. We used IBM SPSS® Modeler14.2 to perform this analysis.

Ethical considerations

Because questions included in this survey could cause participants to re-experience the disaster, which could lead to re-traumatization, care was taken to ensure that students did not feel forced to participate. Before beginning the survey, students were provided with a thorough explanation and asked to participate only if they agreed with the survey's purpose. A summary of the study was published on the university's medical department website, and the participants' right to withdraw from the study, even after receiving the survey, was emphasized.

With respect to participation in voluntary activities, we informed all participants that their participation in voluntary activities would not affect their futures or student evaluations. We also established a procedure to anonymize the data, as the surveys included participants' names. We also stipulated that, should the results be published, used in academic presentations, or made publicly available, the anonymity of the data would be scrupulously maintained.

This study was approved by the Ethics Committee of Tohoku University Graduate School of Medicine (Registration number 2013-1-151) and the student welfare committee at the university's medical department.

Results

Survey response rates and composition

Table 1 shows the numbers of surveys distributed and returned for each of the four surveys. The four surveys were distributed to a total of 2,669 undergraduate and graduate students who attended Tohoku University School of Medicine between 2011 and 2013 (excluding data from stu-

Table 1. Numbers of surveys distributed and collected.

Times of Surveys (Month. Year)	Department of Medicine			Department of Health Sciences			Graduate School			Unknown*	Overall		
	Distribution	Collection	Collection Rate	Distribution	Collection	Collection Rate	Distribution	Collection	Collection Rate	Collection	Distribution	Collection	Collection Rate
1st Survey (Apr. 2011)	688	322	46.8%	152	59	38.8%	846	84	9.9%	7	1,686	472	28.0%
2nd Survey (July. 2011)	690	197	28.6%	606	290	47.9%	846	136	16.1%	17	2,142	640	29.9%
3rd Survey (Feb. 2012)	580	271	46.7%	458	310	67.7%	854	86	10.1%	14	1,892	681	36.0%
4th Survey (Apr. 2013)	610	307	50.3%	454	308	67.8%	673	55	8.2%	8	1,737	678	39.0%

*Affiliation was not written.

Table 2. Question items used on each survey.

Question Items	Times of Surveys			
	1st Survey	2nd Survey	3rd Survey	4th Survey
Location at the time of the disaster	●	●		
State of surroundings at the time of the earthquake	●	●		
Conditions of those close to the students	●	●	●	●
Any later changes in victims' status		●	●	●
Life after the earthquake disaster	●			
Participation in voluntary activities related to the disaster	●	●		
Place where volunteered	●			
Content of volunteer duties	●			
Period of volunteering	●			
Physical health problems	●	●	●	●
Later changes to physical health problems		●	●	●
Mental health problems	●	●	●	●
Later changes to mental health problems		●	●	●
Desire for counseling	●	●	●	●
Free Response	●	●	●	●

dents who just enrolled in a course in 2012 and 2013), and 1,383 (51.8%) returned at least one survey.

Because the survey questions were designed to facilitate understanding of the students' experiences during the disaster and subsequent changes in those experiences, such as those involving physical and mental health, combinations of questions were selected for each survey to reflect the passage of time. As a result, the sets of questions in the four questionnaires varied according to the timing of the surveys, as shown in Table 2.

Survey participants' experiences during the earthquake

Table 3 shows the students' locations when the earthquake occurred. Overall, "other" was the largest category, followed by "home" and "hometown." The breakdown of "other" responses showed that, because the earthquake occurred during the spring break, many students were away from the campus, travelling, shopping, or attending club training camps. Looking at data from the academic department, the order of the frequencies for medical students' locations during the disaster was similar to that of the remainder of the sample ("other," followed by "home" and "hometown"). However, many of the fourth-year students (third-year students at the time of the disaster) were in one of the lecture halls attending a mock academic conference, which is part of the regular curriculum. For health sciences students, "home" was the most frequent response, followed by "other" and "hometown." In contrast, many of the graduate students had been in hospitals during the earthquake, and as a result, "other" was followed by "regional hospital" and "university hospital." The breakdown of "other" for graduate students showed that there were also cases in which the participants had been at a research facility or other workplace when the disaster occurred. As a possible anomaly in the data, it is likely that first-year health science students (who had not yet entered university at the time of the disaster) erred in choosing "university lecture building," perhaps meaning they had been in a high school or preparatory school lecture hall.

Table 4 shows that 476 students experienced loss, injury, or damage to their surroundings during the disaster, much of which was due to damage to homes and property. The proportion of students who experienced the destruction of buildings, injury to themselves or others was approximately 5%, these were possible sources of trauma. The results of a chi-square test examining department affiliation and each type of disaster-related harm suggested a possible relationship between department and "at least half of a building was destroyed," "only the household fixtures and furniture were damaged," "there was hardly any damage," and "other damage," as independence was rejected at the 1% level. Adjusted residuals, relative to the expected values, were significantly higher when the residual was positive and lower when it was negative. The residual analysis p values were: for $p < 0.01$ for $r > 2.58$ and $p < 0.05$ for $r > 1.96$. As 20% or more of all cells displayed an expected frequency of less than 5, "you were harmed or wounded" and "someone else was harmed" fell outside the suitability level for a chi-square test. The frequency for "at least half of a building was destroyed" was significantly high for graduate students but nonsignificant for medical and health sciences students. Of the students who indicated that "only fixtures and furnishings were damaged," the incidence of the response was highest for graduate students, followed by health science students, while it was very low for medical students. Of the students who indicated that "there was hardly any damage," the frequency of the response was high for medical students, low for graduate students, and

Table 3. Location at the time of the earthquake ($n = 875$*).

Students' Year†	Place						Total
	University Lecture Building	University Hospital	Regional Hospitals	Home	Hometown	Other	
Department of Medicine							
1st Year	0 (0.0%)	0 (0.0%)	0 (0.0%)	19 (26.4%)	29 (40.3%)	24 (33.3%)	72 (100.0%)
2nd Year	0 (0.0%)	1 (2.2%)	0 (0.0%)	18 (39.1%)	4 (8.7%)	23 (50.0%)	46 (100.0%)
3rd Year	5 (6.1%)	2 (2.4%)	0 (0.0%)	21 (25.6%)	14 (17.1%)	40 (48.8%)	82 (100.0%)
4th Year	50 (84.7%)	0 (0.0%)	1 (1.7%)	0 (0.0%)	0 (0.0%)	8 (13.6%)	59 (100.0%)
5th Year	0 (0.0%)	1 (1.6%)	1 (1.6%)	21 (33.9%)	13 (21.0%)	26 (41.9%)	62 (100.0%)
6th Year	0 (0.0%)	1 (1.8%)	10 (17.5%)	12 (21.1%)	12 (21.1%)	22 (38.6%)	57 (100.0%)
Subtotal	55 (14.6%)	5 (1.3%)	12 (3.2%)	91 (24.1%)	72 (19.0%)	143 (37.8%)	378 (100.0%)
Department of Health Sciences							
1st Year	3‡ (2.5%)	0 (0.0%)	0 (0.0%)	43 (35.8%)	44 (36.7%)	30 (25.0%)	120 (100.0%)
2nd Year	1 (2.5%)	0 (0.0%)	0 (0.0%)	11 (27.5%)	10 (25.0%)	18 (45.0%)	40 (100.0%)
3rd Year	1 (1.9%)	0 (0.0%)	0 (0.0%)	23 (42.6%)	11 (20.4%)	19 (35.2%)	54 (100.0%)
4th Year	2 (2.2%)	1 (1.1%)	2 (2.2%)	46 (51.7%)	10 (11.2%)	28 (31.5%)	89 (100.0%)
Subtotal	7 (2.3%)	1 (0.3%)	2 (0.7%)	123 (40.6%)	75 (24.8%)	95 (31.4%)	303 (100.0%)
Graduate School							
Master's Course	10 (14.9%)	6 (9.0%)	11 (16.4%)	11 (16.4%)	2 (3.0%)	27 (40.3%)	67 (100.0%)
Doctoral Course	12 (9.4%)	33 (26.0%)	40 (31.5%)	10 (7.9%)	2 (1.6%)	30 (23.6%)	127 (100.0%)
Subtotal	22 (11.3%)	39 (20.1%)	51 (26.3%)	21 (10.8%)	4 (2.1%)	57 (29.4%)	194 (100.0%)
Total	84 (9.6%)	45 (5.1%)	65 (7.4%)	235 (26.9%)	151 (17.3%)	295 (33.7%)	875 (100.0%)

The percentage in parentheses by the number of responses in each grade.

*1st, was responded to the second survey persons.

†1st, 2nd investigation at the time of the school year.

‡Health Sciences 1 year, may have been mistaken for a lecture building of highschool and prep the choice of university lecture building was considered.

nonsignificant for health science students. The frequency of "other damage" was high for graduate students, low for medical students, and nonsignificant for health science students.

Student participation in voluntary activities

Table 5 shows students' participation in voluntary activities; 35.4% of the students participated in voluntary activities within 6 months of the disaster. The result of a chi-square test to examine the relationship between academic department and voluntary activity participation was significant. According to the residual analysis, the frequency of participation in voluntary activities was significantly high for medical students, significantly low for health science students, and nonsignificant for graduate students. Voluntary activities consisted mainly of clearing tsunami debris, operating evacuation shelters, and sorting and distributing relief goods. There were also students who provided assistance with medical treatment on behalf of the medical school (Table 6).

Experience of harm to student finances and individuals close to students

Table 7 shows the students' experiences of harm to their finances and individuals close to them. About 40% of the students indicated that those close to them were disaster victims, and 6.4% of all respondents indicated that they experienced difficulties with their domestic finances as a result of the disaster. The results of a chi-square test examining department affiliation and each questionnaire item were significant. According to the residual analysis, frequencies for "someone was harmed," "home and property was damaged," and "domestic finances became difficult," were significantly high for graduate students and significantly low for medical students. The frequencies for "no damage" were significantly high for medical students and significantly low for graduate students. Frequencies for both items were nonsignificant for health science students.

Disaster-related harm, physical distress, mental distress, and desire for counseling

Table 8 shows the numbers of student responses indicating disaster-related harm, physical distress, and mental distress for each of the four surveys. The results of chi-

Table 4. State of surroundings at the time of the earthquake (Multiple answers allowed).

	Department of Medicine ($n = 373$)	Department of Health Sciences ($n = 303$)	Graduate School ($n = 193$)	χ^2 value	Degree of Freedom	Test Result
At least half of a building was destroyed						
Count	6	5	12	12.279	2	**
% within affilation	1.60%	1.60%	5.70%			
Ajusted residuals	−1.7	−1.3	3.5**			
Only the household fixtures and furniture were damaged						
Count	134	133	111	24.148	2	**
% within affilation	35.50%	42.40%	52.90%			
Ajusted residuals	−3.9**	2	4.5**			
You were harmed or wounded						
Count	1	2	3	3.075	2	n.s.
% within affilation	0.30%	0.60%	1.40%			
Ajusted residuals	—	—	—			
Someone else was harmed						
Count	3	4	6	4.681	2	n.s.
% within affilation	0.80%	1.30%	2.90%			
Ajusted residuals	—	—	—			
There was hardly any damage						
Count	218	148	58	41.039	2	**
% within affilation	57.80%	47.30%	27.60%			
Ajusted residuals	4.9**	0	−5.9**			
Other (Some type of damage occurred)						
Count	15	21	20	8.666	2	*
% within affilation	4.00%	6.70%	9.50%			
Ajusted residuals	−2.5*	0.4	2.5*			

n.s., non-significant. *$p < 0.05$, **$p < 0.01$.

Table 5. Students' participation in voluntary activities ($n = 886$).

		Department of Medicine	Department of Health Sciences	Graduate School	χ^2 value	Degree of Freedom	Test Result
Participated	Count	166	76	72	23.151	2	**
	% within affilation	42.60%	25.10%	37.30%			
	Ajusted residuals	3.9**	−4.6**	0.6			
Did not participate	Count	224	227	121			
	% within affilation	57.40%	74.90%	62.70%			
	Ajusted residuals	−3.9**	4.6**	−0.6			

**$p < 0.01$.

square tests examining each of the three items by survey were significant, and frequencies for each item in Survey 4, conducted two years after the disaster, were significantly small, while at least 50% of the students had been affected by some type of disaster-related harm 6 months after the disaster.

Table 9 shows how students' responses regarding their experiences of disaster-related harm and physical and mental distress changed with time after the disaster. The results of chi-square tests examining the trends in disaster-related harm and physical and mental distress were significant. The results demonstrated that each type of problem gradually decreased in the year following the disaster, although physical and mental distress took two years to resolve. However, the results also showed that a small number of students' experiences of problems remained unchanged or worsened; further, approximately 20% of the students who were experiencing physical and mental distress did not improve over time. The results of chi-square tests examining harm status according to survey and distress status were

Table 6. Place and content of volunteer activities (n = 177).

Activity Location and Content	Department of Medicine	Department of Health Sciences	Graduate School
Areas affected by tsunami			
Removal of debris	33	3	2
Operation of evacuation shelters/areas	32	1	2
Sorting and distributing relief goods	37	3	3
Medical Support	16		9
Other	10	1	3
University hospital			
Removal of debris	8		
Operation of evacuation shelters/areas	10		
Sorting and distributing relief goods	19		
Medical Support	24		1
Other	8		2
Medical institutions in areas affected by tsunami			
Removal of debris	3		
Operation of evacuation shelters/areas	5		
Sorting and distributing relief goods	6		
Medical Support	6		5
Other	2		1
Areas affected by tsunami, but not in medical institutions			
Removal of debris	7		1
Operation of evacuation shelters/areas	5		1
Sorting and distributing relief goods	6		
Medical Support	3		
Other	4		1
Other			
Removal of debris	3		
Operation of evacuation shelters/areas	6	2	2
Sorting and distributing relief goods	7	4	2
Medical Support	3	1	2
Other	20	1	2

Questions about location and content of volunteer activities were only included in the first survey.

significant for all surveys (Table 10), suggesting that students who experienced disaster-related harm complained of physical or mental distress more frequently relative to students who had not experienced harm.

Table 11 shows the responses to items concerning the desire for counseling for each survey. In Surveys 1-3, 3-4% of students required (desired or already received) counseling. The results of chi-square tests examining the three responses regarding desire for counseling for each survey were significant. Residual analysis indicated that, for Survey 1, "no desire" was chosen most frequently, followed by "desire" and "already receiving." In contrast, for Surveys 2, 3, and 4, "no desire" was chosen most frequently, followed by "already receiving" and "desire".

Associations between experience of disaster-related harm, physical and mental distress, and participation in voluntary activities

In order to examine the relationships between "someone was harmed," "home and property was damaged," "domestic finances became difficult," "I experience physical distress," "I experience mental distress," and "I participated in voluntary activities," we performed a covariance structure analysis, a cluster analysis, and an association analysis.

Covariance structure model

In the covariance structure analysis, we examined several models to identify the most suitable and chose a four-level cause-and-effect sequence model (Fig. 1). The three observed variables, "someone was harmed" (personal harm), "home and property were damaged" (building damage), and "domestic finances became difficult" (financial

Table 7. Conditions of individuals close to the students (n = 1,374) (Multiple answers allowed).

	Department of Medicine (n = 592)	Department of Health Sciences (n = 527)	Graduate School (n = 255)	χ^2 value	Degree of Freedom	Test Result
Someone was harmed						
Count	18	29	22	12.078	2	**
% within affilation	2.90%	5.10%	7.70%			
Ajusted residuals	−2.9**	0.6	2.9**			
Home and property was damaged						
Count	157	156	113	27.165	2	**
% within affilation	25.00%	27.70%	39.40%			
Ajusted residuals	−3.1**	−0.9	5.1**			
Domestic finances became difficult						
Count	31	34	29	10.733	2	**
% within affilation	4.90%	6.00%	10.10%			
Ajusted residuals	−2.1*	−0.5	3.2**			
No damage						
Count	421	345	123	41.069	2	**
% within affilation	67.10%	61.20%	42.90%			
Ajusted residuals	4.3**	0.5	−6.1**			

*$p < 0.05$, **$p < 0.01$.

Table 8. Number of students who reported disaster-related harm and mental or physical distress in each survey.

Survey (n)	Students Who Answered Yes	χ^2 value	Degree of Freedom	Test Result	Adjusted residuals
Experienced some type of disaster-related harm					
1st Survey (472)	259 (54.90%)	266.24	3	**	6.5**
2nd Survey (650)	404 (62.20%)				12.4**
3rd Survey (661)	189 (28.60%)				−8.0**
4th Survey (668)	169 (25.30%)				−10.1**
Physical Distress					
1st Survey (467)	33 (7.10%)	15.809	3	**	1.1
2nd Survey (651)	54 (8.30%)				2.9**
3rd Survey (632)	36 (5.70%)				−0.4
4th Survey (668)	22 (3.30%)				−3.5**
Mental Distress					
1st Survey (460)	74 (16.10%)	24.989	3	**	0.9
2nd Survey (651)	119 (18.30%)				2.9**
3rd Survey (632)	103 (16.30%)				1.2
4th Survey (668)	61 (9.10%)				−4.9**

**$p < 0.01$.

problems), were assigned to Level 1, and latent variables, which were not observed directly, were assigned to Levels 2 and 3. Of the observed variables, we hypothesized that the latent variables represented "impediments to daily living" and "disaster stress" and formulated a partial least squares (PLS) model, assigning the observed variables "I experience physical distress" (physical distress), "I experience mental distress" (mental distress), and "I participated in voluntary activities" (voluntary activity participation) to Level 4. Because these data were expressed as categorical or binary variables, we used Bayesian estimation. As a result, the model's suitability level, indicated by the posterior predictive distribution probability, was $p = 0.39$ (p values approaching 50% indicate suitability; and conversely, values approaching zero indicate that the model has low predictive utility). In the figure, the error notations e1-e4 indicated a possibility that factors outside the observed and hypothesized latent variables may have affected each variable. The effects of "personal harm," "building damage," and "financial problems," on "impediments to daily living"

Table 9. Changes over time in status of disaster-related harm and mental and physical distress.

At the Time of the-	2nd Survey		3rd Survey		4th Survey		χ^2 value	Degree of Freedom	Test Result
	%	Adjusted residuals	%	Adjusted residuals	%	Adjusted residuals			
Change in Status of Harm	(n = 586)		(n = 597)		(n = 634)				
No problem	33.80%	−15.5**	70.50%	6.6**	73.20%	8.6**	245.332	6	**
Improved†	52.00%	13.1**	21.80%	−6.1**	21.10%	−6.8**			
No change	12.60%	5.5**	6.20%	−1.6	4.40%	−3.8**			
Worsened‡	1.50%	0.3	1.50%	0.2	1.30%	−0.4			
Physical and Mental Distress	(n = 618)		(n = 611)		(n = 640)				
No problem	50.00%	−9.0**	69.70%	3.4**	72.80%	5.6**	92.596	6	**
Improved†	18.80%	6.3**	9.30%	−2.5*	8.00%	−3.9**			
No change	29.90%	5.3**	19.10%	−2.5*	18.80%	−2.9**			
Worsened‡	1.30%	0.3	1.80%	1.7	0.50%	−2.0*			

† "Improved" means that the answer "Alleviated" was selected.
‡ "Worsened" means that the answer "Grew stronger" or "Newly appeared" was selected.
*$p < 0.05$, **$p < 0.01$.

Table 10. Relationship between status of disaster-related harm and mental/physical distress in each survey.

	With Distress	Without Distress	χ^2 value	Degree of Freedom	Test Result
1st Survey					
Harmed in some way	66 (26.80%)	180 (73.20%)	20.911	1	**
No harm	20 (9.8%)	184 (90.20%)			
2nd Survey					
Harmed in some way	101 (26.50%)	280 (73.50%)	19.103	1	**
No harm	28 (11.8%)	209 (88.20%)			
3rd Survey					
Harmed in some way	55 (30.20%)	127 (69.80%)	28.861	1	**
No harm	52 (12.2%)	375 (87.80%)			
4th Survey					
Harmed in some way	32 (19.80%)	130 (80.20%)	29.974	1	**
No harm	26 (5.5%)	451 (94.50%)			

**$p < 0.01$.

were 1.669, 1.043, and 1, respectively, indicating that the effect of personal harm was the strongest. In addition, "disaster stress" affected "physical distress" and "mental distress" at ratios of 0.591 and 1, respectively. The relationship between "impediments to daily living" and "disaster stress" (0.137) demonstrated that there were some students for whom physical or mental distress was affected by an increase in disaster stress when daily living was affected by some type of harm. Finally, the relationship between disaster stress and voluntary activity participation (0.104) indicated that some of the students who were experiencing disaster stress had participated in voluntary activities.

Cluster analysis

To understand these phenomena more clearly, the sample data were grouped via cluster analysis and examined. The results classified the students into the following five groups (Table 12).

Cluster 1: A group of 40% of the students who reported no harm or distress did not participate in voluntary activities.

Cluster 2: A group of 13% of the students with various combinations of personal harm, building damage, financial problems, physical or mental distress, and voluntary activity participation.

Cluster 3: A group of 18.7% of the students, who suffered no harm or distress and participated in voluntary activities.

Cluster 4: A group of 12.5% of the students with combinations of absence of personal harm, financial problems, or physical distress and presence of building damage, mental distress, and participation in voluntary activities.

Cluster 5: A group of 15.8% of the students, who only

Table 11. Desire for counseling.

	Desire for Counseling	Desire Already Receiving	No Desire	χ^2 value	Degree of Freedom	Test Result
1st Survey						
Count	8	6	447	839.926	2	**
% within each survey	1.70%	1.30%	97.00%			
Ajusted residuals	−145.7**	−147.7**	293.3**			
2nd Survey						
Count	11	14	614	976.122	2	**
% within each survey	1.70%	2.20%	96.10%			
Ajusted residuals	−202.0**	−199.0**	401.0**			
3rd Survey						
Count	6	17	550	1,012.471	2	**
% within each survey	1.00%	3.00%	96.00%			
Ajusted residuals	−185.0**	−174.0**	359.0**			
4th Survey						
Count	2	12	623	1,191.62	2	**
% within each survey	0.30%	1.90%	97.80%			
Ajusted residuals	−210.3**	−200.3**	410.7**			

**$p < 0.01$.

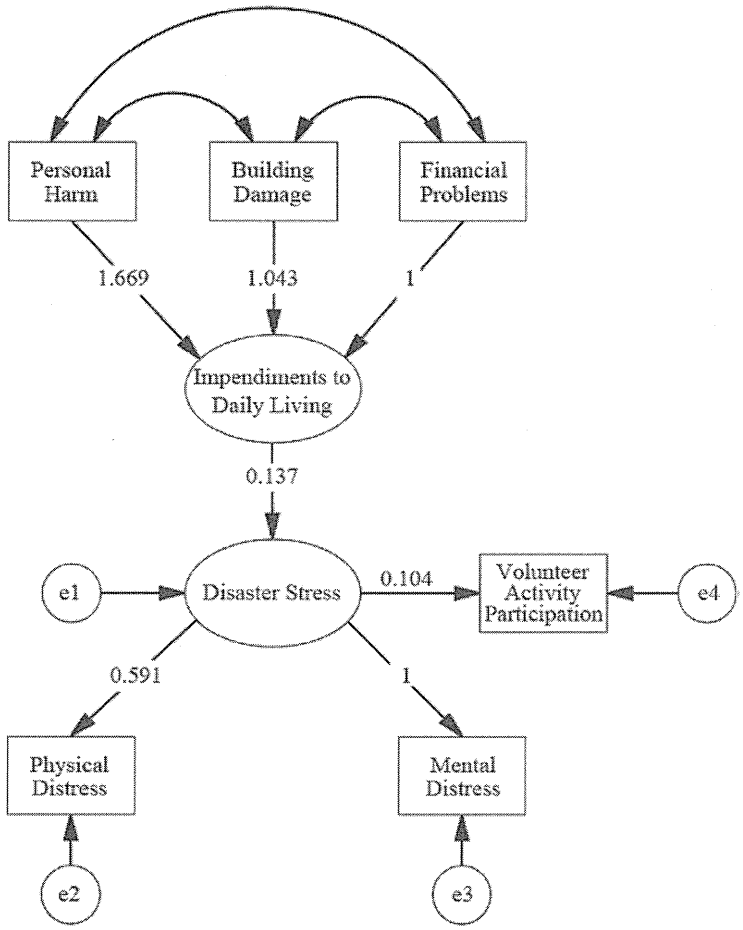

Fig. 1. Covariance Structure Model for Harm, Physical/Mental Distress, and Participation in Volunteer Activities.
Posterior predictive distribution probability that indicates the model's suitability level: $p = 0.39$*.
*The closer the p value is to 50%, the more suitable a model is. Values closer to 0 indicate that the model has a low predicative utility.

Table 12. Results of cluster analysis.

	Cluster Component Ratio	Personal Harm	Building Damage	Financial Problems	Voluntary Activities	Physical Distress	Mental Distress
Cluster 1	40.0%	No (100.0%)	No (100.0%)	No (100.0%)	Did not participate (100.0%)	No (100.0%)	No (100.0%)
Cluster 3	18.7%	No (100.0%)	No (100.0%)	No (100.0%)	Participated (100.0%)	No (100.0%)	No (100.0%)
Cluster 5	15.8%	No (100.0%)	Yes (100.0%)	No (100.0%)	Did not participate (100.0%)	No (100.0%)	No (100.0%)
Cluster 2	13.0%	No (61.1%)	No (52.8%)	No (61.8%)	Did not participate (61.8%)	No (59.0%)	No (63.9%)
Cluster 4	12.5%	No (100.0%)	No (64.5%)	No (100.0%)	Did not participate (59.4%)	No (97.8%)	No (65.9%)

suffered building damage and did not experience physical or mental distress or participate in voluntary activities.

The five groups each showed distinct characteristics: Clusters 1, 3, and 5 did not exhibit physical or mental distress, while Clusters 2 and 4 complained of physical or mental distress or both. Cluster 2, in particular, was recognized as the group that required the most attention, because members not only experienced harm and physical or mental distress, which required intervention, but also tended to participate in voluntary activities.

Association analysis (possible motivation for participating in voluntary activities)

We performed an association analysis to generate rules according to department to determine which sets of response conditions were related to "voluntary activity participation," "physical distress," and "mental distress." In the rule generation, in order to avoid producing a large number of rules and as a cutoff for rule strength, threshold values were set at 5% for support and 50% for confidence, and the maximum number of conditions in an itemset was set to 5. When no rules that exceeded the threshold values were generated, the confidence threshold was lowered to 30-40% and the analysis repeated. The rules that were generated are shown in Table 13. All of the rules generated yielded consequent voluntary activity participation. None had consequences of physical or mental stress. In Survey 1, when medical students had experienced building damage but no physical or mental distress or other harm, a cause-and-effect relationship with participation in voluntary activities was shown at support values of 16-21% and confidence values of 50%. When health science students had experienced building damage and graduate students had experienced building damage and mental distress but no other harm, a cause-and-effect relationship was also indicated. However, in the graduate student rules, support was less than 6%, which was low relative to the rules for the other departments, and the confidence value was 40%, which was also somewhat low. In Survey 2, the medical students' main possible motivation for participation in voluntary activities was the experience of building damage, with a rather high confidence value of 45%, and although support was low, the experience of financial problems may also have been a strong motivation for participation in voluntary activities. Although confidence values in the 30% range were rather low, for health sciences students, voluntary activity participation may have been motivated by having experienced building damage but not by physical or mental distress. For the graduate students, experience of mental distress, financial problems, and building damage combined to form various reasons for participating in voluntary activities, each with a 5-10% support value and confidence values exceeding 50%.

Discussion

Based on the results of a series of four surveys completed by undergraduate and graduate students at Tohoku University School of Medicine following the March 11, 2011 Great East Japan Earthquake, this study investigated the frequencies of and interrelations between direct and indirect types of harm suffered by students, the effects of the disaster on their mental and physical health, and related behaviors.

The Great East Japan Earthquake occurred on a weekday afternoon, during which almost all of the undergraduate students were absent from the campus due to the spring break. Although the locations at which they experienced the disaster consequently differed, at least 40% of the students were at the university, in the university hospital, at home near the university, or in regional hospitals. This proportion was even larger for graduate students, of whom approximately 70% experienced the earthquake in these locations. With respect to the other students, 20% of the medical students and 25% of the health science students were from affected communities. While the hometowns of the students differed somewhat from year to year, many resided in affected areas; for example, of the students who enrolled at the university in 2012, approximately 40% and 73% of the medical and health sciences students, respectively, were from the Tohoku region. Of these students, approximately 67% of the medical students and 56% of the health sciences students were from Iwate, Miyagi, or Fukushima prefectures, which sustained extensive damage due to the disaster (e.g., the tsunami; from the 2012 Guide to the Tohoku University School of Medicine). Therefore, approximately 27-40% of the undergraduate students who had reported that they had returned home were believed to have experienced the disaster in these heavily affected