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Research paper

Trajectories for Post-traumatic Stress Disorder Symptoms Among Local Disaster Recovery Workers Following the Great East Japan Earthquake: Group-based Trajectory Modeling

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ABSTRACT

Background: As many local municipality and medical workers were involved in disaster recovery duties following the Great East Japan Earthquake (GEJE) on March 11, 2011, the aim of this work was to elucidate the distinct trajectories for post-traumatic stress disorder (PTSD) symptoms and associated factors among these personnel. They confronted a diverse range of stressors both as survivors and as relief workers; however, little is known about their longitudinal PTSD symptoms.

Methods: The participants were 745 local municipality and hospital medical workers [average age: 43.6 ± 9.5 years, range: 20 – 66 years; 306 (59%) women] involved in disaster recovery duties following the GEJE. PTSD symptoms were measured using the Japanese version of the PTSD Checklist Specific Version (PCL-S) at four time points: 14, 30, 43, and 54 months after the GEJE. Using group-based trajectory modeling, distinct trajectories were elucidated.

Results: We identified five distinct PTSD symptoms profiles: resistance (n = 467, 62.7%), subsyndromal (n = 181, 24.3%), recovery (n = 47, 6.3%), fluctuating (n = 26, 3.5%), and chronic (n = 24, 3.2%). The trajectories differed according to the post-disaster working conditions and personal disaster experiences.

Limitations: Potential selection bias resulting from the limited number of participants who completed all waves. The survey was conducted in one region of the disaster area.

Conclusions: The majority of participants remained stable, with a relatively small group classified as chronic and fluctuating. Our results highlight the importance of improved working conditions and sustained monitoring of workers responding to natural disasters.

Introduction

The trajectories for post-traumatic stress disorder (PTSD) symptoms among people exposed to major disasters are known to evolve in complex ways (Bonanno et al., 2010; Galatzer-Levy et al., 2018; Norris et al., 2009). A recent review (Galatzer-Levy et al., 2018) that analyzed studies from different types of disasters, including human-made/technological disasters, natural disasters, and adult civilian traumas or accidents, showed that four trajectories were consistently identified: Resilience, never showing more than mild distress; Recovery, initially showing above threshold symptoms that decrease gradually to normal levels over time; Chronicity, showing pronounced symptoms from onset and thereafter; and Delayed onset, elevations above the diagnostic threshold that emerge following a significant delay. Although the majority of survivors initially exhibit psychological distress and/or deterioration in their functional abilities, approximately two-thirds do not require treatment from mental health professionals and show resilience, recovery, or subsyndromal (elevated symptoms below the diagnostic threshold) symptomatology (Galatzer-Levy et al., 2018; Norris et al., 2009). Conversely, about one-third of people exposed to the disaster exhibit chronic distress or dysfunction. Among those with chronic symptoms, some exhibit severe symptoms from the

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initial phase of the disaster, whereas others deteriorate over time and exhibit delayed onset or fluctuating symptoms (cyclical course moving above and below the diagnostic threshold) (Galatzer-Levy et al., 2018; Norris et al., 2009).

Characteristics of major disasters differ and multiple factors, including pre-, peri-, and post-disaster personal and social factors influence the consequent mental health of affected individuals, including PTSD, depression, anxiety, grief, substance abuse, suicidal ideation, and non-specific distress (Bonanno et al., 2010; Norris et al., 2002a). Among adult survivors, demographic characteristics such as female sex and younger age are associated with adverse outcomes (Norris et al., 2002a). One of the important factors relates to the type of disaster. Disasters caused by humans or a technological fault tend to exhibit a stronger psychological impact than that of natural disasters because human-caused disasters, such as mass violence and terrorist attacks, symbolize human callousness and carelessness (Galea et al., 2005; Neria et al., 2008; Norris et al., 2002b). Further, the average exposure dose among study participants tended to be higher in the studies of human-made/technological disasters because in large-scale natural disasters, affected areas and populations tend to be broad, which leads researchers to include mixed populations that often consist of both direct and indirect victims (Neria et al., 2008). However, even in natural disasters, direct victims, such as those who lost family members or been forced to evacuate (Van Griensven et al., 2006), affected people who lack social support (Brewin et al., 2000) or exhibit ongoing stressors (Cerda et al., 2013a), and persons with a history of physical or mental illnesses are known to be at higher risk of PTSD (Brewin et al., 2000; Norris et al., 2002a). Additionally, the sociocultural backgrounds of the affected populations modify the mental health effects of disasters (Davidson et al., 2013). For example, Asians have been reported to be at lower risk of developing PTSD after traumatic events (Roberts et al., 2011). Because populations affected by major natural disasters tend to be larger than those affected by human-made/technological disasters, identification of vulnerable populations and factors related to their psychological outcomes is essential for appropriate program planning and implementation of psychological interventions (Neria et al., 2008).

Not only the general population but also first responders and disaster recovery workers who engage in relief activities are known to suffer from a diverse range of psychological symptoms (Benedek et al., 2007; Bills et al., 2008). In particular, varying conditions, such as PTSD, acute stress disorder, depression, and anxiety disorders, have been shown repeatedly among first responders and recovery workers responding to major disasters (Benedek et al., 2007; Bills et al., 2008; Smith et al., 2019) who may work continually to assist survivors and restore the local community during the initial phase of a disaster and may also continue to live in the vicinity as disaster survivors. These workers may not only suffer personal traumas and losses (Sakuma et al., 2015; Ueda et al., 2017) but also experience secondary traumatic stress because of their frequent contact with other survivors, while trying to live an ordinary life in the affected location (Creamer and Liddle, 2005). Compared with traditional first responders, who are temporarily deployed to a disaster site, local workers confront a diverse range of stressors over a longer period of time. Previous studies have shown that in local recovery workers, mental health consequences of disasters were affected by both personal and workplace factors, such as prior psychiatric history, personal grief, financial difficulties, loss of colleagues, and longer hours spent at the disaster site (Pietrzak et al., 2014; Wang et al., 2013).

In Japan, once a large-scale disaster occurs, local municipality workers and hospital medical workers of disaster base hospitals are supposed to engage in disaster response and recovery, which often continue for a prolonged period. For example, from immediately after a disaster, municipality workers will be involved in a variety of tasks, including management of evacuation centers, damage assessment, management of temporary morgues, disposal of disaster debris, and restoration of public services. Subsequently, these workers engage in long-term reconstruction activities, including building and managing temporary houses, restoring damaged homes, constructing infrastructure, reconstructing industry, and providing health services to victims (Miyagi Prefecture, 2015). Medical workers of disaster base hospitals exhibit a central role in accepting and transporting injured and sick people after the disaster, and the hospitals function as headquarters for medical relief teams from different parts of Japan, including disaster dispatch medical care teams (DMATs) consisting of doctors, nurses, and medical clerks, and provide outreach emergency care for victims at the disaster site and medical care for evacuees at shelters (Homma, 2015). Outreach activities of medical teams, including DMATs, continue until local hospitals and clinics become functional again, which is often prolonged after major disasters. There have been calls to evaluate the post-disaster mental health consequences for local municipalities and medical workers and to develop adequate support (Matsumoto et al., 2016; Shigemura et al., 2016).

Recently, studies on the trajectories of PTSD symptoms among first responders and recovery worker accumulated; however, all of these studies, to date, have been concerned with the World Trade Center (WTC) disaster of September 2001 (Feder et al., 2016; Pietrzak et al., 2014; Welch et al., 2016), which was a human-made disaster. These studies have demonstrated that trajectories of PTSD symptoms among disaster recovery workers are diverse and that approximately 20%–30% of these workers are affected by long-term adverse mental health outcomes classified as chronic or delayed-onset trajectories. However, the PTSD symptoms in recovery workers with different sociocultural backgrounds who respond to large-scale natural disasters remain unclear.

With regard to the GEJE, previous cross-section studies concerning PTSD symptoms in first responders (Fushimi, 2012; Nishi et al., 2012) and recovery workers (Sakuma et al., 2015; Shigemura et al., 2012) have revealed a relatively low prevalence of probable PTSD among these workers. However, the, longitudinal progression and diversity of their PTSD symptoms and the factors related to ongoing PTSD symptoms remain to be clarified. Group-based trajectory modeling (Nagin and Tremblay, 2001) is one of the useful approaches for elucidating the heterogeneous trajectories of PTSD symptom after exposure to major disasters; it enables clinicians to estimate the proportion of workers who require prolonged support. This information along with information about potentially modifiable risk factors is essential for mental health professionals and policymakers who plan and implement mental health intervention for first responders and disaster recovery workers.

The aim of this study was to identify and describe the trajectories of PTSD symptoms among local disaster recovery workers following the GEJE disaster. Recognition of the trajectories of PTSD symptoms and risk factors related to each trajectory will contribute to developing specific countermeasures to protect the mental health of these local workers.

Methods

Great East Japan Earthquake (GEJE)

The GEJE struck the Northeastern part of Japan on March 11, 2011. It was one of the largest earthquakes ever recorded in Japan, measuring 9.0 on the Richter scale. The earthquake triggered a huge tsunami, killing more than 18,000 people and destroying approximately 400,000 houses. In the Miyagi prefecture, which was closest to the earthquake's epicenter, more than 10,000 lives were lost. All of the cities and towns along the coastal regions of the prefecture were severely damaged (Miyagi Prefecture, 2015). Because such a large area was devastated by the GEJE, the process of local community reconstruction faced many difficulties and was delayed at length. More than 20,000 people were forced to live in prefabricated temporary housing 5 years after the disaster (Miyagi Prefecture, 2016).

Participants

In this prospective observational study, PTSD symptoms and associated factors were assessed among local municipality workers and medical workers (i.e., doctors, nurses, pharmacists, medical technologists, midwives, and ancillary medical personnel) of the disaster base hospital of district A, located in the coastal area of Miyagi prefecture. Participants were recruited at the time of the annual health survey at each workplace. The area was among the hardest hit by the tsunami; approximately 2% of the population was lost, and > 30% of the houses collapsed entirely (National Police Agency, 2013). The damage experienced here was much higher than the average seen in Miyagi prefecture (0.5% of the population lost; 9% of houses totally collapsed) (National Police Agency, 2013). After the GEJE, municipality workers of the affected areas had been involved in large-scale and multi-year post-disaster reconstruction activities in addition to their ordinary duties, and chronic staff shortages afflicted municipality offices in the affected areas (Kohara, 2013). Exhaustion of medical workers has also been a concern. Disaster relief activities by the medical workers and medical relief teams lasted for as long as 6 months. After relief activities, disaster-based hospitals were overwhelmed with an increase in emergency patients and outpatients even 12 months after the GEJE because most local hospitals and clinics in the affected area were damaged by the disaster, and approximately 30% of them were permanently closed (Jiji Press, 2012).

Using self-administered questionnaires, the study was conducted at four time points after the GEJE: 14 months (wave 1), 30 months (wave 2), 43 months (wave 3), and 54 months (wave 4).

Of all the 1,335 workers who were employed in the local municipalities or disaster base hospitals of district A at the time of wave 1, 1,233 (92.4%) were eligible to participate in the surveys. The 102 (7.6%) workers who started working after the GEJE were not included in the study. To maintain the longitudinal aspect of the analysis, the inclusion criteria of the study were workers who responded to the first and more than one of the subsequent three surveys, and therefore, workers who did not participate in wave 1 or those responding only in wave 1 were excluded from the study. A total of 939 workers (76.2% of eligible workers) participated in the wave 1 survey, and among them, 745 workers [60.4% of eligible workers consisting of local municipality workers (n = 434) and hospital medical workers (n = 311)] participated in at least one of the subsequent three surveys and were thus included in the study. The mean age of the participants in wave 1 was 43.6 ± 9.5 (range: 20 – 66) years and 306 (59%) participants were women.

Measurements

Demographic characteristics

In wave 1, the demographic characteristics (age, sex), personal risk factors, “displacement”, “dead or missing family members”, and “near-death experience” were surveyed because direct exposure to a disaster has been consistently associated with increased risk of PTSD (Galea et al., 2005). Additionally, “pre-disaster treatment for physical illness” and “pre-disaster treatment for mental illnesses” were surveyed because prior history of physical and mental illnesses have been repeatedly shown to be important risk factors for increased risk of PTSD as well (Brewin et al., 2000; Norris et al., 2002a). Workplace factors, such as “supervisory work status,” were surveyed because higher status with more responsibility may be a stressor after disasters (Kasl et al., 1981). To assess exposure related to the workplace, “mainly disaster-related work” and “dead or missing colleague(s)” were surveyed (Galea et al., 2005). To assess general distress at current workplace, “lack of communication” and “lack of rest” were surveyed because ongoing stressors have been associated with post-traumatic stress after a disaster (Cerda et al., 2013b; Galea et al., 2008). All questions about personal and workplace factors only required a “yes” or “no” answer (Table 1).

Table 1
Participant characteristics at the first survey (n = 745)

	N	%
Sex		
Female	439	58.9
Male	306	41.1
Age (years)		
20–39	270	36.2
40–59	474	63.6
60+	1	0.1
Workplace factors		
Supervisory work status	73	9.8
Mainly disaster-related work [a]	170	22.8
Lack of communication [b]	151	20.3
Lack of rest [c]	340	45.6
Dead or missing colleague(s)	124	16.6
Personal factors		
Displacement [d]	177	23.8
Dead or missing family members(s)	47	6.3
Near-death experience [e]	408	54.8
Pre-disaster treatment for physical illness	168	22.6
Pre-disaster treatment for mental illness	31	4.2
Probable PTSD (PCL-S ≥ 44)		
14 months (n = 745)	62	8.3
30 months (n = 505)	23	4.6
43 months (n = 524)	25	4.8
52 months (n = 582)	31	5.3

Notes. PTSD, post-traumatic stress disorder; PCL-S, PTSD checklist-specific version.
Total score of PCL-S ranges from 17 to 85. A cutoff score was set at ≥44 to indicate probable PTSD.
[a] Data missing for five participants
[b] Data missing for one participant
[c] Data missing for four participants
[d] Data missing for one participant
[e] Data missing for three participants

Risk factors

Personal factors were as follows: (1) “displacement”—whether the worker was displaced from prior housing to temporary or another type of housing (e.g., a relative's house) because of the damage caused by the earthquake or tsunami; (2) “dead or missing family member (s)”—whether a worker's family member was killed or still missing; (3) “near-death experience”—whether the worker had experienced a life-threatening situation due to the earthquake or tsunami; (4) “pre-disaster treatment for physical illness”—whether the worker received medical treatment for physical illness just prior to the GEJE; and (5) “pre-disaster treatment for mental illness”—whether the worker received treatment for mental illness just prior to or at any time before the GEJE.

Workplace factors were as follows: (1) “supervisory work status”—whether the worker's position was higher than that of a manager; (2) “mainly disaster-related work”—whether the worker subjectively felt that they spent more than half of his or her occupational effort on disaster-related duties for the previous 14 months (i.e., since the earthquake); (3) “dead or missing colleague(s)”—whether the worker's colleagues were killed or still missing; (4) “lack of communication”—whether the worker felt at the time of survey that workplace communication was lacking; and (5) “lack of rest”—whether the worker felt at the time of survey that he or she was not obtaining sufficient rest because of occupational duties.

All the factors were assessed at wave 1, except for pre-disaster treatment for physical and mental illnesses, which were assessed at waves 2 and 3. Data from wave 2 were used for analysis of participants who completed both waves 2 and 3 or those who completed only wave 2, whereas data from wave 3 were used for analysis of participants who completed only wave 3.

Outcomes

The severity of PTSD symptoms was measured using the Japanese version of the PCL-S adapted to be specific to the GEJE, of which reliability and validity have been confirmed (Iwasa et al., 2016; Suzuki et al., 2017). The PCL-S is a widely used questionnaire to assess the severity of PTSD symptoms among people who experienced a specific traumatic event (McDonald and Calhoun, 2010; Weathers, 1996). The PCL-S consists of 17 items corresponding to DSM-IV PTSD symptoms criteria B (re-experiencing), C (avoidance/numbing), and D (hyperarousal) (American Psychiatric Association, 1994). Each item contains a Likert-type response format ranging from 1 ("not at all") to 5 ("extremely"), and the total score ranges from 17 to 85. A cutoff score was set at ≥ 44 to indicate probable PTSD (Blanchard et al., 1996). Cronbach's alpha values for the four waves were 0.953, 0.939, 0.945, and 0.952.

Ethical issues

The data used in this study were acquired during health examinations conducted by each workplace. To protect the privacy of the participants, the questionnaire was distributed and collected within each workplace by the person who oversaw the health of staff members. We obtained the electronic data but not personal information. Therefore, we could not obtain written informed consent from each participant. Instead, we disclosed the study information, including the objectives and procedure, to the subjects and provided them with the opportunity to refuse participation. All of the participants who completed and returned the questionnaires were deemed as having consented to the study. Moreover, the names of administrative regions, cities, or towns were anonymized so that the workplaces of the participants were not specified. The study protocol and consent procedure were reviewed and approved by the Ethics Committee of Tohoku University Graduate School of Medicine (reference number: 2012-1-197).

Data analysis

Group-based trajectory modeling

Group-based trajectory modeling is a type of growth mixture modeling used to identify distinct subpopulations showing similar progressions in their symptoms or behaviors (Nagin and Odgers, 2010; Nagin and Tremblay, 2001). Various researchers conducted group-based trajectory modeling to elucidate progression of psychological symptoms over time, including studies of PTSD symptoms among disaster responders and recovery workers at the WTC disaster (Pietrzak et al., 2014; Welch et al., 2016).

Missing values for the total score of PCL-S [wave 2, 240 (32.3%) cases; wave 3, 221 (29.7%) cases; wave 4, 163 (21.9%) cases] were imputed using a multiple imputation method and the MI procedure in SAS version 9.4 software (SAS Institute Inc., Cary, NC) under the assumption that data were randomly missing (Yuan, 2011). To mitigate selection bias, the MI procedure creates 25 imputed datasets and the first dataset was used to perform subsequent group-based trajectory modeling.

We performed group-based trajectory modeling using the PROC TRAJ procedure in SAS (Jones and Nagin, 2007; Jones et al., 2001), based on the tutorial by Andruff et al. (Andruff et al., 2009), to identify distinct subgroups with similar patterns of GEJE-related PTSD symptoms over time. The analysis started with modeling a single group trajectory, with a cubic specification for trajectory shape and dropped non-significant polynomial terms; the model of each additional trajectory was compared with the previous model until no substantial improvement in the model fit existed. The better model fit was based on an estimate of the log Bayes factor (Andruff et al., 2009), which is calculated by doubling the remainder after subtracting the sample-size adjusted Bayesian information criterion (SSA-BIC) value of the simpler model (i.e., the model with the smaller number of trajectories) from the more complex model (i.e., the model with the larger number of trajectories). Values greater than 10 were interpreted as very strong evidence for a better fit. In addition, entropy (average posterior probabilities of group membership, > 80%), parsimony, and interpretability of our participants were also considered (Andruff et al., 2009). Each participant was assigned to the group for which their average posterior probability was greatest. Descriptive analysis of demographic characteristics was also performed using SAS.

Next, we performed $\chi 2$ tests with categorical variables and analysis of variance with continuous variables to explore whether the participants' characteristics differed between the PTSD symptoms trajectory groups. For post-hoc multiple comparison, we performed an adjusted standardized residuals (ASRs) analysis for χ^2 tests and Bonferroni correction to control for type I error in analysis of variance. ASRs greater or less than ± 2.0 are considered to be significantly higher or lower ($p < 0.05$) than chance (MacDonald and Gardner, 2000). A two-sided p-value < 0.05 was used to indicate significance. We reported our study using the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline (Elm et al., 2007) and Guidelines for Reporting on Latent Trajectory Studies (the GRoLTS-Checklist) (van de Schoot et al., 2016).

Results

Of 939 workers who participated in wave 1, 745 workers who responded to more than one of the subsequent three surveys were included in this study (an overall comparison between the included and excluded participants is shown in Supplementary Table 1). The mean score of the PCL-S at wave 1 among the subjects included in this study (n = 745, 28.0 ± 11.0) did not differ from that of the subjects excluded from the study (n = 194, 27.4 ± 10.2) (t = 0.72, p = 0.47). Compared with the participants included in the analysis, the excluded participants were older (t = 5.2, p < 0.001) and were more likely to have factors of supervisory work status (χ^2 = 14.15, p < 0.001) and dead or missing family members(s) (χ^2 = 8.09, p < 0.01). Of the 745 subjects included in the study, 505 (67.8%), 524 (70.3%), and 582 (78.1%) participated in wave 2, wave 3, and wave 4, respectively. The number of participants completing all waves was 274 (29.2% of the participants at wave 1).

Table 1 describes the demographic profile, workplace, and personal attributes of disaster workers. Of 745 workers [average age: 43.6 (± 9.5, range: 20 – 66) years; 306 (59%)women], 24% were forced to evacuate their original houses, and 55% experienced fear of death because of their involvement in the GEJE. Overall, the percentage of participants with possible PTSD (PCL-S ≥ 44) (Blanchard et al., 1996) was 8.3% (highest) in wave 1 (14 months) and dropped to 4.6% in wave 2 (30 months). The percentages remained stable through waves 3 (43 months) and 4 (54 months) at 4.8% and 5.3%, respectively.

Table 2 describes the fit indices calculated for each model (Akaike information criterion, AIC; BIC; SSA-BIC, estimated log Bayes factor, entropy, number and percentage of participants assigned to each group). Trajectory model 5 exhibited the best fit statistics (SSA-BIC = −9763.56, estimated log Bayes factor = 108.5, entropy = 0.93) relative to those of trajectory models 4 (SSA-BIC = −9810.80, estimated log Bayes factor = 135.6, entropy = 0.93) or 6 (SSA-BIC = −9785.87, estimated log Bayes factor = −12.3, entropy = 0.93). The average posterior probabilities of each trajectory in trajectory model 5 were between 86 and 98% and were higher than the above-mentioned criteria (80%); therefore, we selected trajectory model 5 as final and most parsimonious (Figure 1).

Table 3 describes the characteristics of the participants assigned to each group: resistance (n = 467, 62.7%), never showing more than mild distress; subsyndromal (n = 181, 24.3%), elevated symptoms below the diagnostic threshold; recovery (n = 47, 6.3%), initially showing above threshold symptoms but that decreased gradually to normal level over time; fluctuating (n = 26, 3.5%), cyclical course moving above and below the diagnostic threshold, and; chronic

Table 2
Fit information for the group-based trajectory model

Model	AIC	BIC	SSA-BIC	Estimated Log Bayes Factor	Entropy	Group 1 n (%)	Group 2 n (%)	Group 3 n (%)	Group 4 n (%)	Group 5 n (%)	Group 6 n (%)
1	−10722.7	−10734.7	−10731.9	–	1	745 (100.0)	-	-	-	-	-
2	−10072.1	−10102.1	−10095.2	1301.0	0.98	632 (84.0)	113 (16.0)	-	-	-	-
3	−9832.6	−9865.6	−9858.0	479.1	0.96	531 (70.7)	175 (24.1)	39 (5.3)	-	-	-
4	−9764.8	−9812.8	−9801.7	135.6	0.93	482 (64.1)	172 (23.3)	53 (7.4)	38 (5.2)	-	-
5	−9710.5	−9779.5	−9763.6	108.5	0.93	467 (62.3)	181 (24.2)	47 (6.8)	26 (3.6)	24 (3.2)	-
6	−9716.7	−9806.7	−9785.9	−12.3	0.93	466 (62.1)	180 (24.4)	47 (6.6)	28 (3.7)	24 (3.2)	0 (0.0)

Notes. AIC, Akaike information criterion; BIC, Bayesian information criterion; SSA-BIC, sample-size adjusted BIC; Estimated log Bayes factor = 2 × [(SSA-BIC of the current model) – (SSA-BIC of the previous model)], values greater than 10 are interpreted as very strong evidence for a better fit; Entropy = average of the posterior group membership; Groups 1 to 6 shows the n (%) values of the participants assigned to each group according to the highest posterior group membership.

(n = 24, 3.2%), showing pronounced symptoms from onset and thereafter.

As summarized in Table 3, post-hoc analysis showed differences in multiple workplace factors, such as mainly disaster-related work (χ^2 = 31.67, p < 0.001), lack of communication (χ^2 = 29.55, p < 0.001), and lack of rest (χ^2 = 42.53, p < 0.001) as well as in all of the personal factors of displacement (χ^2 =14.96, p < 0.01), dead or missing family members(s) (χ^2 =12.79, p < 0.05), near-death experience (χ^2 = 26.28, p < 0.001), pre-disaster treatment for physical illness (χ^2 = 26.97, p < 0.001), and pre-disaster treatment for mental illness (χ^2 = 27.38, p < 0.001) across the trajectory groups. Post-hoc comparison of total PCL-S scores was performed at each wave after Bonferroni correction (p < 0.05/10 = 0.005); at wave 1, the scores of all the groups were significantly different; at wave 2, the scores of all the groups were significantly different, except those for chronic and fluctuating; at wave 3, the scores of all the groups differed significantly; and at wave 4, the scores of all the groups were significantly different, except those for chronic and fluctuating and for recovery and subsyndromal.

Post-hoc comparison using ASRs (Supplementary Table 2), for which those greater or less than ± 2.0 indicated factors significantly (p < 0.05) higher or lower than chance, revealed that “mainly disaster-related work” in the subsyndromal (3.0) and recovery (3.3) trajectories exhibited positive ASRs, indicating that the participants included in the subsyndromal and recovery trajectories demonstrated factors significantly greater than chance and in the resistance trajectory (−5.3) exhibited a negative ASR, indicating that the participants exhibited a factor significantly less than chance; “lack of communication” in the chronic (2.1), fluctuating (3.3), and recovery (2.1) trajectories exhibited positive ASRs and in the resistance (−4.6) trajectory exhibited a negative ASR; “lack of rest” in the chronic (3.8), recovery (3.2), and subsyndromal (2.8) trajectories exhibited positive ASRs and “in the resistance (−5.8) trajectory exhibited a negative ASR; “displacement” in the chronic (3.1) trajectory exhibited a positive ASR and in the resistant (−2.8) trajectory exhibited a negative ASR; “dead or missing family members(s)” in the chronic (3.0) trajectory exhibited a positive ASR and in the resistant (−2.0) trajectory exhibited a negative ASR; “near-death experience” in the chronic (2.4) and recovery (3.1) trajectories exhibited positive ASRs and in the resistance (−4.5) trajectory exhibited a negative ASR; “pre-disaster treatment for physical illness” in the chronic (4.3) and subsyndromal (2.1) trajectories exhibited positive ASRs and in the resistance (−3.9) trajectory exhibited a negative ASR; “pre-disaster treatment for mental illness” in the chronic (3.1), fluctuating (2.9), and recovery (2.3) trajectories exhibited a positive ASR and in the resistance (−3.6) trajectory exhibited a negative ASR.

Discussion

This is the first study to elucidate the trajectories of PTSD symptoms among local municipalities and hospital medical workers who responded to a large-scale natural disaster. These trajectories were subsequently classified into five groups. The majority of workers, i.e., those who followed a resistant (63%) or subsyndromal trajectory (24%) exhibited minimal to mild symptoms and remained stable throughout the study period [i.e., 14 months (wave 1), 30 months (wave 2), 43 months (wave 3), and 54 months (wave 4) after the GEJE]. Initially, 6% of workers showed severe (PCL-S ≥ 44) symptoms indicating probable PTSD (Blanchard et al., 1996) but recovered in the subsequent period (recovery trajectory), 3% experienced persistent severe PTSD symptoms (chronic trajectory), and 4% followed a fluctuating chronic course with ranges of moderate to severe symptoms (fluctuating trajectory). However, because our study lacked data for the period immediately after the disaster or the first year after the disaster, names of the trajectories are based on patterns observed during the study period (14–54 months after the GEJE) and careful interpretation is therefore necessary. For example, participants whose trajectory was classified as “resistance”

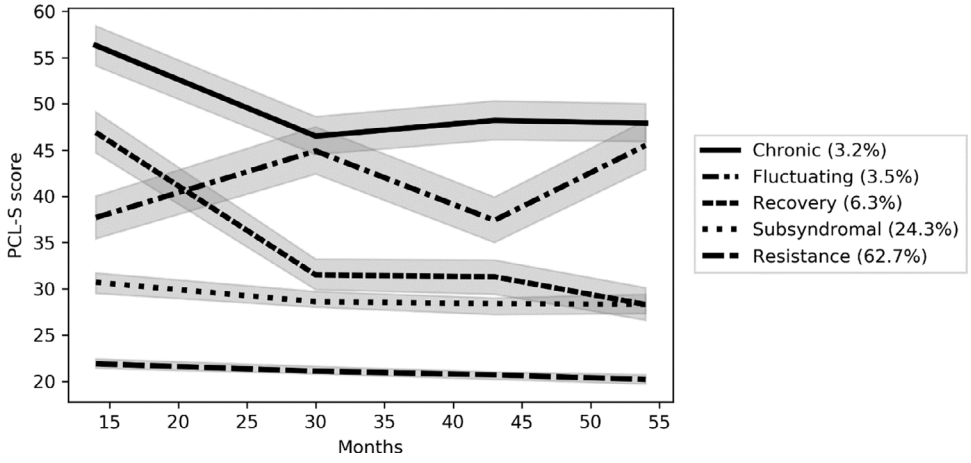

Figure 1. Trajectories of post-traumatic stress disorder (PTSD) symptoms among local disaster recovery workers following the Great East Japan Earthquake (n = 745)
Note. PCL-S; PTSD Checklist specific version. Total score of PCL-S ranges from 17 to 85. Gray area represents the 95% confidence interval for each trajectory. Names of the trajectories are based on patterns observed during the study period (14–54 months after the GEJE) and careful interpretation is therefore necessary. For example, participants whose trajectory was classified as “resistance” may not have been resilient immediately after the disaster.

Table 3
Participant Characteristics of the Post-traumatic Stress Disorder Symptoms Trajectory Group

	Resistance		Subsyndromal		Recovery		Fluctuating		Chronic			
	N	%	n	%	n	%	n	%	n	%	χ^2/F	p
Number of participants	467	62.7	181	24.3	47	6.3	26	3.5	24	3.2		
Average posterior probability		95.8		86.3		91.0		92.8		98.4		
Sex												
Female	272	58.2	107	59.1	31	66.0	16	61.5	13	54.2	1.35	0.853
Male	195	41.8	74	40.9	16	34.0	10	38.5	11	45.8		
Age (years)												
20–39	184	39.4	57	31.5	13	27.7	7	26.9	9	37.5	0.85	0.495
40–59	282	60.4	124	68.5	34	72.3	19	73.1	15	62.5		
60+	1	0.2										
Workplace factors [a]												
Supervisory work status	51	10.9	18	9.9	3	6.4	0	0.0	1	4.2	4.98	0.290
Mainly disaster-related work [b]	77	16.5	56	30.9	20	42.6	8	30.8	9	37.5	31.67	<0.001
Lack of communication [c]	70	15.0	45	24.9	15	31.9	12	46.2	9	37.5	29.55	<0.001
Lack of rest [d]	175	37.5	99	54.7	32	68.1	14	53.8	20	83.3	42.53	<0.001
Dead or missing colleague(s)	75	16.1	30	16.6	8	17.0	5	19.2	6	25.0	1.45	0.835
Personal factors												
Displacement [e]	95	20.3	49	27.1	15	31.9	6	23.1	12	50.0	14.96	0.005
Dead or missing family members(s) [f]	23	4.9	11	6.1	5	10.6	3	11.5	5	20.8	12.79	0.012
Near-death experience [g]	226	48.4	110	60.8	36	76.6	17	65.4	19	79.2	26.28	<0.001
Pre-disaster treatment for physical illness [h]	84	18.0	51	28.2	12	25.5	7	26.9	14	58.3	26.97	<0.001
Pre-disaster treatment for mental illness [i]	10	2.1	8	4.4	5	10.6	4	15.4	4	16.7	27.38	<0.001

PTSD score (PCL-S)	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	F	p
Wave 1 (14 months) [j]	21.9	(4.5)	31.0	(5.4)	47.8	(5.8)	37.8	(4.9)	56.3	(8.4)	587.9	<0.001
Wave 2 (30 months) [k]	21.0	(3.4)	29.0	(4.8)	31.6	(6.5)	45.4	(8.1)	46.5	(9.2)	421.3	<0.001
Wave 3 (43 months) [l]	20.7	(3.7)	28.6	(6.1)	31.5	(8.0)	37.4	(7.7)	48.2	(10.9)	270.9	<0.001
Wave 4 (52 months) [m]	20.1	(3.5)	28.6	(6.0)	28.4	(6.6)	45.7	(8.4)	48.0	(9.3)	387.1	<0.001

Notes. PTSD, post-traumatic stress disorder; PCL-S, PTSD checklist-specific version. Total score of PCL-S ranges from 17 to 85; ASR, adjusted standardized residual, pos-hoc comparison for χ^2 test, values greater or lesser than ± 2.0 are considered to be significantly higher or lower than chance.

[a] Workplace factors were assessed at Wave 1 (14months), except for Pre-disaster treatment for physical illness and Pre-disaster treatment for mental illness which were collected at Wave 2 (30 months) and 3 (43months).

[b] Mainly disaster-related work in the subsyndromal (3.0), and recovery (3.3) trajectories had positive ASRs, indicating that the participants included in the subsyndromal and recovery trajectories had factors significantly greater than chance. The resistance trajectory (−5.3) had a negative ASR, indicating that the participants included in the resistance trajectory had factors significantly less than chance.

[c] Lack of communication in the chronic (2.1), fluctuating (3.3), and recovery (2.1) trajectories had a positive ASR and in the resistance (−4.6) trajectory negative ASR.

[d] Lack of rest in the chronic (3.8), recovery (3.2) and subsyndromal (2.8) had positive ASRs and in the resistance (−5.8) trajectory had a negative ASR.

[e] Displacement in the chronic (3.1) trajectory had a positive ASR and in the resistance (−2.8) trajectory had a negative ASR.

[f] Dead or missing family members in the chronic (3.0) trajectory had a positive ASR and in the resistance (−2.0) trajectory had a negative ASR.

[g] Near-death experience in the chronic (2.4) and recovery (3.1) trajectories had positive ASRs and in the resistance (−4.5) trajectory had a negative ASR.

[h] Pre-disaster treatment for physical illness in the chronic (4.3) and subsyndromal (2.1) trajectories had positive ASRs and in the resistance (−3.9) trajectory had a negative ASR.

[i] Pre-disaster treatment for mental illness in the chronic (3.1), fluctuating (2.9), and recovery (2.3) trajectories had positive ASRs and in the resistance (−3.6) trajectory had a negative ASR.

[j] All the groups were significantly different (Bonferroni correction, $p < 0.05/10 = 0.005$).

[k] All the groups were significantly different, except those for chronic and fluctuating (Bonferroni correction, $p < 0.05/10 = 0.005$).

[l] All the groups were significantly different (Bonferroni correction, $p < 0.05/10 = 0.005$).

[m] All the groups were significantly different, except those for chronic and fluctuating and for recovery and subsyndromal (Bonferroni correction, $p < 0.05/10 = 0.005$).

may not have been resilient immediately after the disaster.

In accordance with previous studies (Feder et al., 2016; Pietrzak et al., 2014; Welch et al., 2016), our work revealed diversity in the courses of PTSD symptoms experienced by local disaster recovery workers who responded to the major disaster. Furthermore, the trajectories observed in this study—the majority of participants were resistant or subsyndromal throughout the study period; some participants had chronic symptoms; and some showed recovery over time—are similar to those in people after other types of traumatic events, such as military personnel (Porter et al., 2017), survivors of the severe acute respiratory syndrome (SARS) epidemic (Bonanno et al., 2008), and cancer survivors (Lam et al., 2010). However, the trajectory pattern differed in several ways from the four typical trajectory patterns (i.e., resilience, recovery, chronicity, and delayed onset) described by Galatzer-Levy et al. (Galatzer-Levy et al., 2018). First, our trajectory lacked a delayed onset pattern and instead showed a fluctuating pattern. This difference may be because of variations in the duration of the study periods and characteristics of the study samples. Approximately a third of the studies included in a review by Galatzer-Levy et al. were conducted over a period of several months to 2 years, periods that were much shorter than that in our study. We speculate that if our study had been completed at 30 months after the GEJE (i.e., at Wave 2), most of the participants with fluctuating patterns in our study might have been regarded as demonstrating delayed onset pattern. Another possibility is potential selection bias resulting from the limited number of participants completing all of the waves. When we analyzed the data of the participants who completed the assessments of all four waves, the trajectory pattern was different from that of the participants who completed the assessments of the first wave and any of the following three waves. We present the trajectory of the participants who completed all four waves in Supplementary Figure 1 as well as fit information and comparison of demographics in Supplementary Tables 3

and 4. In this trajectory, "Trajectory 1" resembles the delayed onset pattern.

Another difference observed was the shape of the chronic trajectory of this study, which showed a small amount of recovery above the threshold level of probable PTSD between waves 1 and 2. We speculate that this small recovery may have been due to the characteristics of our participants, who were workers that were able to keep working from the onset of the disaster and for more than several years, so it is that the workers who were deteriorating or maintaining a greater degree of symptoms could not participate in the survey because of resignation or taking temporary leave.

Similarly, to the present analysis, studies of the events surrounding the WTC disaster examined the trajectories of PTSD symptoms for disaster recovery workers. However, the present study differs from those on the WTC in several ways, including the type of disaster, characteristics of the participants, and duration of the follow-up period. Our study targeted non-traditional disaster workers including local government employee and medical workers who continued their involvement in recovery work following the GEJE for 5 years, whereas the WTC studies elucidated the trajectories of first responders (i.e., police) and non-traditional responders (e.g., reconstruction workers) who responded to the terrorist attack and were followed up for 8 – 12 years (Feder et al., 2016; Pietrzak et al., 2014; Welch et al., 2016).

In spite of above-mentioned differences, some similarities in the patterns of progression for PTSD symptoms determined in this and the WTC studies existed. The majority of participants remained stable and showed resistance throughout the study period; a group of participants continued to experience chronic severe symptoms; and some workers exhibited delays in the deterioration or recovery of their symptoms. These patterns seem to be consistent with common post-traumatic stress reaction pathways (Galatzer-Levy et al., 2018; Norris et al., 2009) for survivors and workers affected by large-scale traumatic events.

However, up to 20% – 30% of non-traditional workers who were involved in the WTC disaster showed chronic or delayed courses of deterioration (Feder et al., 2016; Pietrzak et al., 2014) compared with 7% of the subjects identified in this study who followed chronic or fluctuating trajectories. This might be partially explained by the difference in the type of disaster. The risk of PTSD is reportedly higher following disasters caused by humans or technology, such as terror attacks (Galea et al., 2005), and the risk of delayed deterioration is higher after intentional (Santiago et al., 2013) rather than natural disasters. Additionally, preparedness for a disaster, which usually reduces the risk of PTSD (Norris and Murrell, 1988), may have been relatively higher among people in the coastal area of Miyagi prefecture, because the areas were repeatedly subjected to tsunamis at intervals of several decades (Shibahara, 2011). Past experience of tsunamis may have served as a buffer and lessened the impact of the GEJE (Norris and Murrell, 1988).

Cultural (Liddell and Jobson, 2016) and race/ethnic (Roberts et al., 2011) differences may have moderated the effects on mental health following the traumatic events and altered the trajectory of the PTSD symptoms. The relative low prevalence of probable PTSD observed in this study coincides with that reported in previous reports targeting survivors and the disaster responders of the GEJE (Matsumoto et al., 2016). This trend may partly stem from the attitudes or mentality of Japanese people when confronted with extreme adversity, such as "gaman" (patiently persevering in tough times, absorbing losses, and maintaining internal control) and "shouganai" (the belief that the problem cannot be helped) (Goto and Wilson, 2003). International media remarked on the self-restraint of Japanese people in the immediate aftermath of the GEJE: instead of chaos, such as theft or lootings, people calmly waited in line for water and food (Hogg, 2011). However, many of these survivors may have expressed traumatic stress in the form of somatic or behavioral symptoms rather than in the form of emotional symptoms associated with PTSD (Goto and Wilson, 2003). Because this issue was beyond the scope of our study, a wide variety of trauma-related symptoms must be surveyed to elucidate the cultural and race/ethnic differences in response to a large-scale disaster. An alternative speculation is that a lesson that has been passed down in the coastal areas devastated by GEJE exists,"tsunami tendenko" (escape from tsunami by yourself), which calls for a quick evacuation from a tsunami to higher ground without waiting for others. This inherited lesson shared by community members may have fostered mutual trust in advance and reduced feelings of self-reproach after the tsunami disaster (Yamori, 2014).

Because the number of participants classified into the chronic or fluctuating trajectory was relatively small in this study, the analysis of relationships between personal and workplace factors to each trajectory were limited, and they should be interpreted carefully. Overall, compared to the participants who followed a resistant trajectory, those who followed trajectories with more severe PTSD symptoms exhibited more workplace risk factors including disaster-related work, lack of communication, or lack of rest, as well as personal risk factors directly associated with the disaster including displacement, loss of family or near-death experience, and pre-disaster treatment for physical or mental illness. These findings imply that multiple disaster-related workplace and personal stressors or pre-disaster risk factors may affect the trajectories of PTSD symptoms for local disaster recovery workers. The relationships among risk factors and higher symptom trajectories (i.e., chronic and fluctuating) have not been straightforward; for example, "pre-disaster treatment for mental illness" was related not only to the chronic and fluctuating trajectories but also to the recovery trajectory; "mainly disaster-related work" was related to the subsyndromal and recovery trajectories but not with the chronic and fluctuating trajectories. These seemingly inconsistent findings may stem from a lack of statistical power because of the small sample size. Future studies using larger samples will be necessary to elucidate the factors related to chronic or delayed dysfunctional trajectories, as well as those associated with resistance or recovery trajectories. The cross-sectional interaction of these factors and their longitudinal effects also need to be investigated. Sustained monitoring of risk factors from ordinary times and health surveys at fixed intervals post-disaster must be incorporated as psychological intervention policy for local disaster workers.

Our findings showed that both workplace and personal factors affected longitudinal PTSD symptoms, which may result in several significant implications. These findings indicate the importance of both improving overall working conditions and providing individual support for workers with higher exposure to risk factors related to disaster. Continuation of increased amount of work from immediately after a disaster may prevent maintenance of workers' mental/physical health or recovery from personal losses they suffered. Intervention targeting these workers may include measures to encourage taking adequate rest and maintaining interpersonal communications with colleagues (e.g., developing educational programs or leaflets to inform workers of the psychological response after a disaster and stress management techniques as well as to educate supervisory employees about the importance of controlling the disaster-related workload or staff rotation to prevent burn-out) (Suzuki et al., 2014). The importance of rest and good relationships with coworkers has been reported by local government officials responding to the Sichuan earthquake in China in 2008 as well (Wang et al., 2013).

Although Japan is frequently confronted with major natural disasters such as earthquakes, typhoons, and volcanic eruptions almost every year, relatively few studies concerning PTSD exist, and to the best of our knowledge, this is the first study to investigate trajectories of PTSD symptoms among Japanese disaster recovery workers. Previous studies reported relatively low PTSD prevalences (Matsumoto et al., 2016) of 0% (Fushimi, 2012), 3% (Sakuma et al., 2015), and 16% (Kato and Asukai, 2004) among first responders and of 0% (Suzuki et al., 2011) and 9% (Kato and Iwai, 2000) in direct victims, which is much lower than the prevalences reported from Western countries, which range from 10% – 20% among first responders and 30% – 40% among

direct victims (Galea et al., 2005). However, in the case of the Fukushima nuclear disasters (nuclear power plant explosion and a nuclear meltdown that occurred at the Fukushima Daiichi nuclear powerplant, triggered by the tsunami following the GEJE), 30% of workers responding to the Fukushima Daiichi nuclear powerplant (Shigemura et al., 2012) and 22% of municipality workers in the town of Fukushima Maeda et al., 2016, from which all of the residents were temporally forced to evacuate, were considered as exhibiting probable PTSD. Overall, the percentage of probable PTSD (PCL-S ≥ 44) in our study was relatively lower than that of WTC workers and workers responding to the Fukushima nuclear disasters. However, the rates of probable PTSD remained persistent throughout waves 2, 3, and 4 (4.6%, 4.8%, and 5.3%, respectively), and further, 7% of the participants were classified into the chronic and fluctuating trajectories. Since the 12-month prevalence of PTSD in Japan in ordinary times is lower at 0.5% (Kawakami et al., 2005), it is important that mental health professionals and policy makers understand the persistence of the elevated risk of PTSD among local workers responding to major natural disasters over a prolonged period.

Limitations

Several limitations must be noted. First, there may have been a potential selection bias because the number of participants who participated in all of the surveys was small (n = 274, 29.2% of the participants at wave 1). Second, the participants in this study were limited to one region of the extensive disaster area, and participants included in the analysis were required to answer a survey at least twice. Therefore, generalizability to other workers who responded to the GEJE might be limited. Third, we used self-administered questionnaires to measure PTSD symptoms and did not conduct a psychiatric diagnostic interview to confirm the results of the questionnaires. A future study should consider using a clinician-administered structured interview. Fourth, the psychiatric consequence of disaster are not limited to PTSD symptoms and may be expressed as other symptoms such as depression, anxiety, substance abuse, and various physical disorders (Wisnivesky et al., 2011). Overall psychiatric and physical evaluations are necessary when providing care to disaster workers. Fifth, because our study to elucidate the factors related to a chronic or dysfunctional trajectory was relatively small, future studies should prospectively evaluate factors affecting mental health consequences, including past traumatic experiences or stressful life events prior to the survey, in a larger number of participants. Sixth, although post-disaster data on working conditions (i.e., lack of rest and lack of communication) were evaluated dichotomously (“yes”/”no”), quantitative analysis such as comparison of pre-disaster and post-disaster working hours could have elucidated more precisely how working conditions changed after the disaster. At the workplaces of disaster responders, sustained monitoring during ordinary times may help clinicians detect risk factors longitudinally and enable rapid psychological intervention for those at risk. Seventh, our first survey was conducted 14 months after the GEJE, which limited identification of the first year trajectories. The GEJE was so powerful that more than 5,000 aftershocks occurred in the following year, and local government and disaster base hospitals of the affected areas were overwhelmed by their duties; therefore, health surveys of the workers were considered to be a low priority, so we were not able to conduct the survey in the first year.

Conclusion

This study elucidated the diversity in progression of PTSD symptoms among local disaster recovery workers who responded to the GEJE. Although the majority of workers remained stable throughout the study period and showed minimal to mild symptoms, there were several groups of workers who exhibited severe, chronic, and/or fluctuating symptoms. These trajectories for PTSD symptoms seem to be related to multifaceted factors including the effects of workplace and personal experiences associated with the disaster. Our participants, who played dual roles as disaster survivors and support providers, confronted a diverse range of stressors over an extended period of time following the disaster. Because continuous disaster-related and life stressors following disasters are known to influence mental health conditions and functional outcomes (Cerda et al., 2013a; Galea et al., 2008), the multifactorial nature of disaster-based stress must be considered in order to provide care for people experiencing work-related stress or personal experience of a disaster. Future studies are necessary to develop measures to improve mental health care for local workers over a prolonged period.

Author contributions

AS, IU, WS, HM, KM concept and designed the study. AS, IU, KM collected data. AS and KM performed the statistical analysis. AS and KM drafted the manuscript. All authors contributed in interpretation of the data and revision of the manuscript. All authors read and approved the final manuscript.**Figure legends**

Competing Delcaration of Interest

The authors declare no conflict of interest.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jad.2020.05.152.

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