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Predictors of severe psychological distress trajectory after nuclear disaster: evidence from the Fukushima Health Management Survey

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ABSTRACT

Objectives: The Fukushima Daiichi Nuclear Power Plant accident, which occurred after the Great East Japan Earthquake and Tsunami in March 2011, may have a considerable long-term impact on the lives of area residents. The aims of this study were to determine the trajectories of psychological distress using 3-year consecutive data, and to find predictive factors of severe distress that may also prove useful for public health intervention.

Methods: Data were obtained on 12 371 residents who were registered in the municipalities categorised as complete evacuation areas for 3 years after the disaster and who completed an assessment in each of the 3 years.

Results: Using group-based trajectory modelling, we identified four trajectory patterns distinguished by the levels of psychological distress, which gradually improved over time in all trajectories. Subjective sleep insufficiency, problem drinking, poor social support and perception of radiation risk 3 years after the accident were associated with the severity of psychological distress, according to the multivariate analysis.

Conclusions: The identified factors may be useful for community-based mental healthcare over the long term following a nuclear disaster.

Strengths and limitations of this study

- The measure used to assess psychological distress has been validated in Japanese.
- The number of respondents is large, although the response rate declines over time.
- The use of self-rating questionnaires for the assessments offers lower accuracy compared with clinician-administered diagnostic tools.
- Predisaster psychological distress or other mental health problems could not be measured; therefore, we do not know the extent to which these may have influenced the results.

INTRODUCTION

The Fukushima Daiichi Nuclear Power Plant (FDNPP) accident, which occurred in 2011 after the Great East Japan Earthquake (GEJE) and Tsunami, had a significant impact on the lives of residents. It was already known that long-term mental health consequences continue to be a concern after previous nuclear disasters, such as the Chernobyl accident.[1] Three-year trend surveys revealed that the prevalence of non-specific psychological distress, post-traumatic stress response and problem drinking were still high 3 years after the accident.[2] However, even as the population prevalence of psychological distress remains high, the trajectories of individuals' psychological distress may vary.

Longitudinal research on trauma substantiates the presence of heterogeneous symptom trajectories over time.[3–5] Recent studies on these trajectories after disasters show that the majority of individuals do not develop psychopathology, whereas a substantial proportion experience psychological distress or develop mental disorders.[6–8] For example, Bonanno (2013) represented six categories of trajectories of stress responses, including minimal-impact resilience, distress improvement, recovery, delayed symptom elevations, chronic dysfunction and continued pre-existing distress.[9] Most studies have reported at least three or four trajectories, which include minimal impact or resistant resilience or recovery and chronic dysfunction.[5–8 10] Some studies indicate that intentional trauma, for example, terrorism, and non-intentional trauma, for example, motor vehicle accidents, follow different trajectories;[11 12] however, another review failed to show associations between post-traumatic

stress disorder and disaster typology.[13] A longitudinal study was conducted after the nuclear accident at Three Mile Island, following individual trajectories of long-term (10-year) psychiatric distress among 109 mothers of young children and a sharply bipolar division between chronic high distress and continuous low distress was observed.[14] Identification of such trajectories would lead to better overall understanding of long-term psychological distress after a nuclear plant accident, which in turn would enable better planning of mental health services for affected residents.

Cross-sectional studies based on the Fukushima Health Management Survey showed that drinking behaviours[15] and perception of radiation risk[16] were major risk factors for psychological distress. The effects of social support or social networks on mental health have already been reported following the 1964 Niigata earthquake[17] and the Great East Japan Earthquake.[18] It would be worthwhile to investigate whether risk factors associated with psychological distress in previous cross-sectional studies could also be associated with different trajectories of distress over time.

The aim of this study was twofold: to map the trajectories of psychological distress using 3-year consecutive data, and to find predictive factors of severe distress that could also be useful for public health intervention. We hypothesised that subjective sleep insufficiency, problem drinking, negative perception of radiation risk and poor perceived social support are positively associated with distress severity.

METHODS

This study was designed as a cohort study at three time points.

Study population

The study population was 60 432 residents born before 1 April 1998 who were registered in the municipalities categorised as complete evacuation areas during all three fiscal-year (FY) assessments before the FDNPP accident (11 March 2011). The residents had lived in the town of Naraha, Tomioka, Okuma, Futaba or Namie, or in the village of Katsurao or Iitate. To avoid the problem of resettlement, we chose the residents in this area from the original sample of the mental health and lifestyle survey in the Fukushima Health Management Survey.[19]

A total of three mail-based, self-administered assessments were conducted: the FY 2011 assessment was in January 2012, the FY 2012 assessment was in January 2013, and the FY 2013 assessment was in February 2014 ('FY' notation is omitted hereafter to avoid repetition). These assessments were conducted 10, 22 and 35 months after the disaster. The response rates for each assessment were 47.5% in 2011, 39.1% in 2012 and 33.5% in 2013. In total, 12 371 people completed all three assessments (see online supplementary material file).

Assessments

The Kessler 6-item scale (K6)[20] in its validated Japanese version[21 22] was used for assessing psychological distress. The K6 consists of six brief questions about depressive and anxiety symptoms during the past 30 days. All items are measured on a five-point scale, and the assessment can be completed within 2–3 min. The total score (ranging between 0 and 24) has been used as an indicator of serious mental illness or mood and anxiety disorders in the general population. This scale showed adequate internal consistency (α=0.85).[22]

The CAGE (an acronym for Cutting down, Annoyance, Guilt and Eye-opener) is a four-item scale designed as a screening instrument for problem drinking.[23] The total CAGE score (0–4) was used as an index of problem drinking. We used 1/2 cut-off according to a review by the National Institute on Alcohol Abuse and Alcoholism.[24] The Japanese version of the CAGE showed adequate internal consistency (α=0.83) and concurrent validity.[25]

To assess perceived social support, we used the abbreviated Lubben Social Network Scale (LSNS-6).[26] The Japanese version of the LSNS-6 showed adequate internal consistency (α=0.82), test–retest reliability (r=0.92) and validity.[27] The LSNS-6 comprises three questions that evaluate kinship ties and a comparable set of three questions that evaluate non-kinship ties. All items are answered on a five-point Likert-type scale, and the total scale score is an equally weighted sum of the six items (range 0 to 30).

In this study, subjective sleep insufficiency was evaluated by the question, 'Is your total sleep time sufficient or not?' The answers (yes or no) were collected. This question did not include any suggested sleep length.

We also solicited sociodemographic characteristics and information on disaster-related variables. The number of relocations after the disaster was asked because several studies have shown higher general psychological distress and perceived stress in people with particular relocation profiles,[28–30] despite a study that showed protective effects under specific conditions.[31]

Analysis plan

There is growing evidence from longitudinal studies of psychological symptoms following disasters,[4] especially using semiparametric group-based modelling[5 32] or latent growth mixture modelling[33 34] with multiple assessments. This type of modelling is suitable for finding heterogeneity in the longitudinal patterns.[32] Although grouping methods using cut-off scores are also used for longitudinal studies after natural disasters,[35–37] this method has disadvantages: categorising a continuous variable diminishes statistical power, and it is also difficult to find heterogeneity above/below cut-off scores. We thus conducted semiparametric group-based modelling for this study.

All analyses were performed using SAS software, V.9.4 (SAS, Cary, North Carolina, USA). Group-based

trajectory modelling using SAS software with user-written procedure PROC TRAJ[38 39] was used to identify trajectories of psychological distress. The Bayesian Information Criterion (BIC) and Akaike's Information Criterion (AIC) were used to select the best-fitting model. For criteria of trajectory membership, we chose 5% membership, because our aim in this study was to understand the whole picture of the trajectories.

There was a large number of missing data points for the CAGE assessment (the number missing in the original responses was n=6609, or 53.4% of the sample). This is partially due to inclusion of respondents aged 15–19 years, who are prohibited from drinking alcohol in Japan and people who do not habitually use alcohol. We decided to perform a data correction, giving a null point for missing data. For other variables, we did not perform data corrections.

RESULTS

Sociodemographic characteristics and disaster-related variables

Sociodemographic characteristics and disaster-related variables are shown in table 1. About 40% of the study sample was at least 65 years old at the time of the disaster. More than 80% of the respondents reported that their homes were damaged to varying degrees. A total of 45.4% of the respondents had a frequent (5 or more) relocation profile, while 21.4% of the respondents experienced bereavement of a family member or loved one.

Trajectories of psychological distress

The mean scores on the K6 sample-wide were 7.10 (SD 5.92) in 2011, 6.50 (SD 5.68) in 2012 and 5.97 (SD 5.44) in 2013. Comparing goodness-of-fit for models with different numbers of trajectories of psychological distress over time, a four-trajectory model was found to have the best fit (AIC, -93358.38; BIC, -93402.84). The four trajectories using K6 scores are shown in figure 1. The trajectories are distinguished by the average levels of psychological distress during the follow-up (ie, resistant, mild, moderate and severe), and all groups showing parallel trends of gradually improving psychological distress. About half of the sample (n=6170) was categorised into the mild distress group, whose average scores were 5.5 in 2011 and 4.5 in 2013. More than one-quarter of respondents (n=3313) belonged to the moderate distress group, with average scores of 11.9 in 2011 and 9.9 in 2013. Approximately 20% of the sample (n=2244) was categorised into the resistant group, whose average scores were 1.2 in 2011 and 0.80 in 2013, while 5.7% of the sample (n=644) showed severe distress, with consistently high average scores of 18.9 in 2011 and 17.9 in 2013.

Problem drinking and social support among the groups

Mean CAGE and LSNS-6 scores for each group are shown in figure 2. One-way ANOVA revealed a main effect for the CAGE, F (3, 12 367)=29.87, p<0.001, and for the LSNS-6, F (3, 11 661)=131.22, p<0.001. Post hoc tests with Bonferroni correction demonstrated significant differences in CAGE and LSNS-6 scores among the four groups, except for the CAGE score between the moderate and severe distress groups (p=1.0).

Table 1 Sociodemographic characteristics and disaster-related variables of the study sample: evacuees after the March 2011 nuclear disaster in Japan

	Study sample (n=12 371) n
Gender	
Male	5290
Female	7081
Age in 2011 (years)	
15–24	445
25–34	1011
35–44	1347
45–54	1643
55–64	3171
65–74	2719
75–84	1717
≥85	318
Residence registration at time of disaster	
Naraha	1220
Tomioka	2451
Okuma	2041
Futaba	1270
Namie	4232
Katsurao	280
Iitate	877
Education	
Elementary or junior high school	2827
Senior high school	6024
Junior college or professional school	1984
University or graduate school	1092
No answer	444
Disaster-related variables	
Disaster-related home damage	
Yes	9053
No	1948
No answer	1370
Disaster-related bereavement	
Yes	2572
No	9443
No answer	356
Five or more relocations after the disaster, in 2012	
Yes	5477
No	6584
No answer	310

The number of relocations was asked not in 2011, but in 2012.

Perception of radiation risks

The risk perception profile for radiation in each group is shown in table 2. χ^2 tests revealed significant group differences in delayed effects (χ^2=871.0, df=9, p<0.001) and in genetic effects (χ^2=991.7, df=9, p<0.001). The most frequent response in the resistant group was 'Very

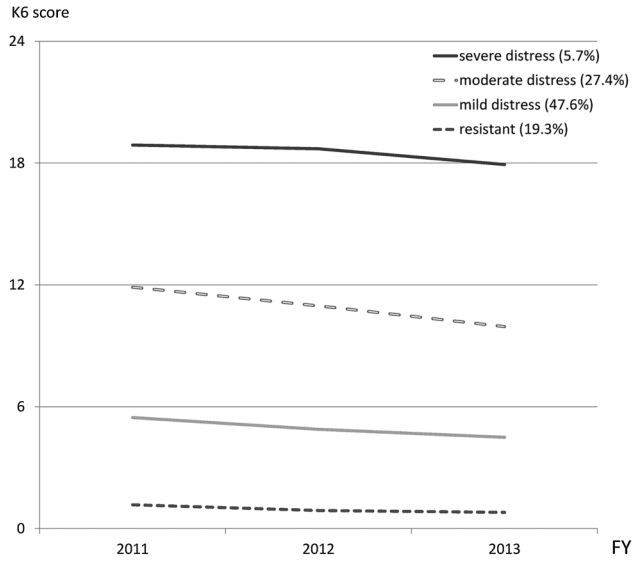

Figure 1 Trajectories of the four-group model of psychological distress.

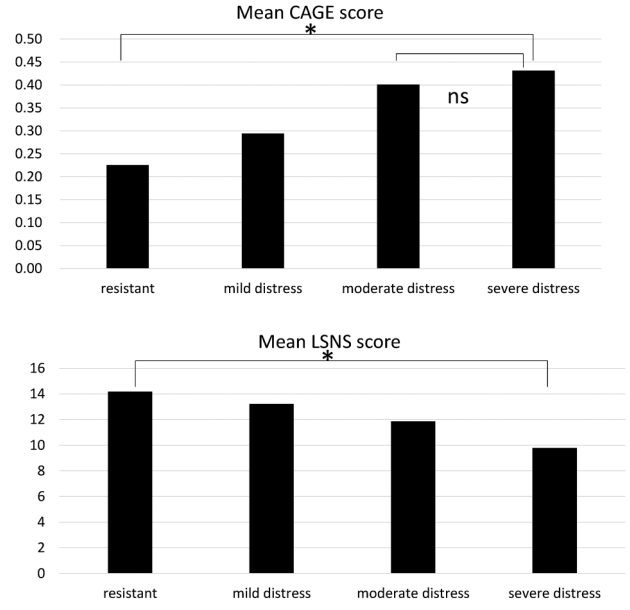

Figure 2 Mean CAGE scores (upper) and LSNS-6 scores (lower) by group. *p<0.05. CAGE, Cutting down, Annoyance, Guilt and Eye-opener; LSNS, Lubben Social Network Scale.

unlikely', whereas approximately half of the respondents in the severe distress group answered 'Very likely' regarding their assessment of delayed effects and genetic effects.

Subjective sleep insufficiency

The overall proportion of subjective sleep insufficiency was 35.8% (N=4424; including missing data N=921). The proportions of subjective sleep insufficiency were 16.7% (N=374) in the resistant group, 32.7% (N=2018) in the mild distress group, 48.8% (N=1616) in the moderate distress group and 64.6% (N=416) in the severe distress group. χ^2 Tests revealed that these group differences were significant (χ^2=972.0, df=3, p<0.001).

Factors related to the severe distress trajectory

In order to explore the factors related to the severe distress group, we conducted logistic regression analysis using a forced entry method. Variables considered in the model were CAGE in 2013 (score≥2 as problem drinking), LSNS-6 score in 2013 (score≤12 as poor perceived social support), and risk perception in 2013: genetic effects ('Very likely' as high perceived risk), adjusting for gender and age as potential confounders in model 1 (table 3). All variables showed significant effects and ORs. The results remained significant after adjusting for disaster-related variables (home damage, bereavement, relocations) as additional potential confounders in model 2 (table 3).

DISCUSSION

Using group-based trajectory modelling, we identified four trajectories of psychological distress over time during the 3-year follow-up, which represented different average levels of psychological distress, and all of which showed gradual improvement. The declining pattern of psychological distress in the long term was in line with studies after the Three Mile Island[40 41] and the Chernobyl[42] accidents. However, the trajectories in this study were approximately parallel, and we could not find heterogeneous patterns of trajectories (eg, recovery or worsening) across the 3 years, in contrast with Bonnano's model.[9] This might be because of the timing of the surveys. The first survey in 2011 was conducted almost 1 year after the disaster, which means that we were not able to differentiate any acute or subacute-phase impact soon after the disaster from the consistent symptom resistance. In a study on depressive trajectories after the 11 September 2001 attacks, drastic changes were observed only between 8 (first assessment) and 14 (second assessment) months after the events and there were only gradual changes at follow-up at 26 and 42 months.[32] In contrast, a study conducted 6 years after the 2004 Indian Ocean tsunami identified four distinct trajectories compared with an indirect exposure group; the observed trajectories included a recovery group characterised by a gradual decrease in post-traumatic symptoms between 1 year and 6 years after the disaster.[10]

Our study demonstrated that the number in the mild distress group (47.6%) that scored around 5 points of K6 was larger than in the resistant group (19.3%). It has been reported that the optimal cut-off points were estimated as 4/5 for the Japanese version of the K6 for screening in a general population, and the prevalence of screened cases in the community sample was 31.3%.[22] Sone *et al* (2016)[36] reported 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) in a tsunami-affected area after the GEJE.

Table 2 Perception of risk of delayed and genetic effects of radiation in 2013, by group

Delayed effects						
Group	Very unlikely N (%)	Unlikely N (%)	Likely N (%)	Very likely N (%)	Data missing N (%)	Total N (%)
Resistant	879 (39.9%)	669 (29.8%)	347 (15.5%)	233 (10.4%)	116 (5.2%)	2244 (100%)
Mild distress	1611 (26.1%)	1970 (31.9%)	1244 (20.2%)	939 (15.2%)	406 (6.6%)	6170 (100%)
Moderate distress	548 (16.5%)	879 (26.5%)	856 (25.8%)	821 (24.8%)	209 (6,3%)	3313 (100%)
Severe distress	67 (10.4%)	94 (14.6%)	146 (22.7%)	273 (42.4%)	64 (9.9%)	644 (100%)
Genetic effects						
Group	Very unlikely	Unlikely	Likely	Very likely	Data missing	Total
Resistant	725 (32.3%)	676 (30.1%)	423 (18.9%)	275 (12.3%)	145 (6.5%)	2244 (100%)
Mild distress	1219 (19.8%)	1826 (29.6%)	1547 (25.1%)	1114 (18.1%)	464 (7.5%)	6170 (100%)
Moderate distress	384 (11.6%)	744 (22.5%)	970 (29.3%)	968 (29.2%)	247 (7.5%)	3313 (100%)
Severe distress	54 (8.4%)	72 (11.2%)	121 (18.8%)	326 (50.6%)	71 (11.0%)	644 (100%)

Another study by Yokoyama *et al* (2014)[43] in the Iwate Prefecture showed that a total of 42.6% of the respondents 6–11 months after the GEJE had moderate (5–12 of K6) or serious (13+ of K6) distress. Compared with these results, our results suggest that residents in the evacuation area in Fukushima Prefecture had persistent psychological distress after the nuclear accident.

Support was found for the hypothesis that subjective sleep insufficiency, problem drinking, poor social support, perception of radiation risk 3 years after the accident and frequent relocations after the disaster were associated with psychological distress trajectories. Among these, perception of radiation risk was a factor unique to nuclear disasters. Our result that those who believed that radiation exposure was very likely to cause delayed and genetic health effects were significantly more likely to be categorised into the severe distress group, is in line with other cross-sectional studies.[16 44] Suzuki *et al* (2015)[16] showed that radiation risks were associated with psychological distress 2 years after the FDNPP accident. Another cross-sectional study conducted with a relatively small sample (n=285) in 2014 in Kawauchi village, which is located within 30 km of FDNPP, revealed that about half of the residents had anxieties about the health effects of radiation on children and about the health effects of radiation on offspring.[44] These results suggest the importance of risk communication as a strategy for preventing severe mental disorders and their consequences, such as depression and committing suicide, which are recognised as major public concerns in Fukushima.[45]

In comparison with other studies after the GEJE, the relationship between poor social support (or social isolation) and psychological distress in Miyagi Prefecture has been reported.[18 36] A longitudinal study with two time points (2011 and 2014) using LSNS-6 and K6[36] showed that being free from social isolation was associated with improvement of psychological distress. Another research group demonstrated that individual and community-level social support were significantly associated with low psychological distress.[18] Separated families and communities in Fukushima have produced one of the main psychosocial consequences of the Fukushima disaster,[46] and postdisaster housing instability may affect both physical and mental health.[28] A relationship between prolonged sleep difficulties and lack of social support after the GEJE has also been reported.[47]

Table 3 Multivariate logistic regression analysis of the severe distress group

Predictor	Model 1 Sociodemographic factors and health-related variables OR (95% CI)	Model 2 Model 1+disaster-related variables OR (95% CI)
Gender (female)	1.38 (1.14 to 1.68)**	1.51 (1.21 to 1.89)**
Age (65 years or more) at the disaster	1.73 (1.43 to 2.10)**	1.82 (1.46 to 2.26)**
Problem drinking (CAGE 2 or more) in 2013	1.62 (1.19 to 2.20)**	1.77 (1.26 to 2.49)**
Subjective sleep insufficiency in 2013	4.01 (3.26 to 4.94)**	3.86 (3.07 to 4.86)**
Poor perceived social support (LSNS-6 12 or less) in 2013	2.31 (1.88 to 2.83)**	2.39 (1.90 to 2.99)**
Perception of radiation risk (genetic effects: very likely) in 2013	3.76 (3.12 to 4.53)**	3.91 (3.17 to 4.83)**
Disaster-related home damage		0.90 (0.68 to 1.20)
Disaster-related bereavement		1.16 (0.91 to 1.47)
Relocation 5 times or more after the disaster (in 2012)		1.26 (1.02–1.55)*

*p<0.05, **p<0.01.

Our results may be useful for facilitating a community-based mental healthcare network in Fukushima. For example, the Fukushima Center for Disaster Mental Health, which has been providing outreach service and psychoeducational programmes for the evacuees, residents and various stakeholders based on the transdisciplinary model, is expected to promote long-term support.[46] It seems easier for the health providers to ask lifestyle habits than to ask psychological symptoms directly. Our results contribute to the better design of interventions on mental health.

The present study has a number of strengths, including the use of questionnaires that have been validated in Japanese and a large number of respondents, even as the response rate declines over time. Before the FDNPP accident, there was no well-designed multiple-assessment study during the initial 3 years after a nuclear accident: in the case of the Chernobyl disaster, no well-designed studies were conducted during the initial 5-year aftermath;[1] and in the wake of the Three Mile Island disaster, large-scale (eg, n>1000) longitudinal studies on mental health were lacking.[14]

Several limitations should be considered in this study. First, the use of self-rating questionnaires for the assessments provides less accuracy compared with the use of clinician-administered diagnostic tools. Second, we could not measure predisaster psychological distress or other mental health problems. Continued pre-existing distress might be misunderstood as disaster-related distress. However, it is understandable in community-based care that predisaster, peridisaster and postdisaster issues coexist both at the personal and community levels. Moreover, as already mentioned, we could not measure acute and subacute phases of post-traumatic distress (ie, <1 year postdisaster). Third, owing to the relatively low response rates, one should not overgeneralise the results.

Despite these limitations, this study demonstrated that poor perceived social support, problem drinking, subjective sleep insufficiency, perception of radiation risk and frequent relocations after the disaster were related to long-lasting psychological distress after the FDNPP accident. Assessing these factors might be effective for community-based mental healthcare after nuclear disasters in the long term. Future research including the continuance of the mental health and lifestyle survey as a part of the Fukushima Health Management Survey is strongly needed to examine longitudinal trajectories and determine both the risk and resilience factors of survivors that will inform interventions and public policies.

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