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Association between earthquake experience and depression 37 years after the Tangshan earthquake: a cross-sectional study

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ABSTRACT

Objective To investigate the association between the Tangshan earthquake and depression after 37 years.

Design and setting A cross-sectional study conducted in Tangshan from 2013 to 2014.

Participants The sample included 5024 participants born before 28 July 1976 the date of the Tangshan earthquake, with available data on their earthquake experiences and depression 37 years post-earthquake.

Outcomes and variables The outcome was depression measured using the Center for Epidemiological Study and Depression Scale. The independent variable was earthquake experience, which was classified into three groups: no earthquake experience, earthquake experience without bereavement and earthquake experience with bereavement. Multivariable logistic regression analysis was used to evaluate the association between earthquake experience and depression after adjusting for gender, age at the time of the earthquake, smoking status, drinking status, education, income, residence in Tangshan 1 to 2 years post-earthquake, hypertension, diabetes and dyslipidaemia.

Results Of the 5024 participants, 641 experienced the Tangshan earthquake, and 98 experienced bereavement due to the earthquake. 37 years after the earthquake, survivors who had lost relatives during the earthquake were nearly three times (OR 2.82, 95% CI 1.24 to 6.39) as likely to have depression as those who had not experienced the earthquake, while those who had not lost relatives were 1.69 times as likely (OR 1.69, 95% CI 0.93 to 3.08). Stratified analyses showed that earthquake was significantly associated with depression in women with (OR 3.51, 95% CI 1.21 to 10.16) or without bereavement (OR 3.07, 95% CI 1.44 to 6.56) but not in men; this association was also significant in individuals over 18 years old at the time of the earthquake with (OR 13.16, 95% CI 3.08 to 56.3) or without bereavement (OR 3.39, 95% CI 1.31 to 8.87) but not in individuals less than 18 years old.

Conclusions 37 years after the Tangshan earthquake, earthquake experience was associated with depression among bereaved survivors, women and individuals over 18 years old at the time of the earthquake.

INTRODUCTION

Depression is predicted to be a major reason for disability around the world by 2030,

Strengths and limitations of this study

► The study investigated the long-term risk of depression 37 years after a major earthquake.

► Participants were stratified by gender and age at the time of the earthquake.

► We were unable to control for every event or factor, such as adverse childhood experiences, other bereavement or current psychological stressors.

► Only participants who were still alive 37 years after the earthquake were able to participate in the study.

according to the WHO.[1] In addition, the chronic and debilitating nature of depression complicates the prognosis of chronic diseases, aggravates various diseases and may lead to suicide.[2–4] Evidence shows that depression is related to demographic characteristics, living habits, education, income and health status.[5–7] Participants exposed to disasters at an early life stage are at an increased risk of depression in the short term (1 to 4 years), independent of age, gender, income, education and other confounders.[8–10] Additionally, studies report that some survivors have psychological problems in the immediate aftermath of disaster trauma; most of these reactions abate over time, and only a minority of survivors develop a long-standing disorder.[11 12] Therefore, long-term evidence is essential to evaluate the effects of disaster on depression.

Findings regarding the long-term impact of disasters on mental health have been mixed. Several studies have reported no significant differences,[13 14] but others have revealed more psychological problems in exposed individuals than in non-exposed individuals for more than a decade after disasters.[10 15 16] Moreover, evidence shows that such effects are increased if survivors suffer from bereavement.[10 12] Additionally, the association

between earthquakes and depression may vary according to age or gender. Studies indicate that overall levels of psychological symptoms may vary among children, adolescents and adults due to differences in physiology and cognition.[17 18] In response to disaster, women appear to develop more intense and longer-lasting psychological symptoms than men.[13 19] However, very few of these studies investigated the long-term effect of earthquakes on depression risk in the Chinese population.

Our study provides a suitable setting for investigating the long-term impact of earthquakes on depression in the Chinese population. The Tangshan earthquake, which occurred in 1976, had a magnitude of 7.8 on the Richter scale.[20] The earthquake caused 242 769 deaths and left 164 851 people severely injured, representing the strongest and deadliest natural disaster in the twentieth century.[20] Since the earthquake, numerous studies have examined the effects of the event on physical health outcomes. These studies report increased risks of diabetes, cardiovascular disease and elevated levels of uric acid among survivors of the Tangshan earthquake even at time points more than 30 years later.[21–23] However, no study to date has examined the long-term effect of the Tangshan earthquake on the risk of depression.

The aim of our study was to examine the long-term effect of disaster on depression 37 years later. We hypothesised that the earthquake-exposed group would be more likely than the non-exposed group to exhibit depression. Furthermore, we expected that bereaved survivors would be more likely to experience depression than non-bereaved survivors. Considering that age and gender may confound the association between earthquake experience and depression, we also performed an analysis stratified by age and gender.

METHODS
Study participants
The participants were selected from the Jidong cohort, an ongoing community-based prospective study in Chinese adults[24 24]. The Jidong community is located in the Caofeidian district of Tangshan City, which is approximately 60 km from the epicentre of the Tangshan earthquake. Cluster sampling was used to select participants. From July 2013 to August 2014, a total of 9078 residents in the Jidong community were recruited to participate in the cohort. Data regarding demographic and behavioural characteristics, insomnia, cognition, depression and biochemical indicators have been collected from this cohort at annual follow-ups since 2013.[25–27] These data were collected using a set of self-administered questionnaires (including the Center for Epidemiological Study and Depression Scale (CES-D)) with the assistance of well-trained research nurses during face-to-face interviews. Biomedical variables were collected by physical examinations and laboratory assessments. Research on this cohort originally examined sub-health and later expanded to

examine depression, cardiovascular health, cerebrovascular health and other areas.[25–28]

In the current study, we excluded 4054 of the 9078 candidate participants according to the following standards: (1) birth date after 28 July 1976 (n=4053), (2) incomplete information on relevant earthquake experience (n=1) and (3) missing values in the surveys for the CES-D measurement scale (n=0). Missing data for confounding variables (60 income variables) were imputed with their mean values among these participants. Ultimately, a total of 5024 individuals were included in this cross-sectional study. The participants in the Jidong Cohort are subjected to a physical examination annually, which is paid for by the community. Therefore, the response rate was almost 100% (5024/5025).

This study was performed according to guidelines from the Declaration of Helsinki. All participants provided written informed consent.

Assessment of earthquake experience
The exposure variable of interest was experience with the earthquake. Earthquake experience and related bereavement were collected through a structured questionnaire. These factors were obtained using the following questions: "Were you in the Tangshan earthquake area in 1976?" and "Did you lose any relatives in the earthquake?"[23] According to the answers to these questions, subjects were classified into three groups: no earthquake experience, earthquake experience without bereavement and earthquake experience with bereavement.

Assessment of current depression
Depressive symptoms were assessed using the CES-D, which was initially developed by the US National Institute of Mental Health in 1977.[29] The Chinese version of the CES-D was translated from the international standard version of the CES-D questionnaire in 1985 by two psychiatrists and was specifically designed to screen for depression.[30] The CES-D questionnaire surveys the frequency of common depressive symptoms over the past week. Each item in the depression assessment section of the questionnaire is scored from 0 (rarely or none of the time, less than 1 day) to 3 (all of the time, 5 to 7 days). The four positive statement items (item 4, I felt that I was just as good as other people; item 8, I felt hopeful about the future; item 12, I was happy; item 16, I enjoyed life) are reverse coded to calculate the total score, which ranges from 0 to 60. A cut-off value of ≥16 has been widely used to define clinically meaningful depressive symptoms.[31–33] All investigators attended a 3-day training course and were licensed before conducting the CES-D interviews.

Assessment of potential covariates
The selected covariates included factors known to be predictive of depression and/or potentially correlated with earthquake exposure, including age at the time of the earthquake, gender, education, income, smoking status, drinking status, residence in Tangshan 1 to 2

years after the earthquake, hypertension, diabetes and dyslipidaemia.

Age at the time of the earthquake was defined as a continuous variable and then a categorical variable ('≤6 years', '6 to 18 years' or '≥18 years'). The average monthly income of each family member was categorised as '<¥3000', '¥3000 to 5000' or '>¥5000'. Educational level was classified into three categories: 'illiteracy or primary school', 'middle school or high school' and 'university or above'. Residence in Tangshan 1 to 2 years after the earthquake was classified as 'yes' and 'no'. Smoking status was classified as 'yes' (current smoker or quit <12 months ago) and 'no' (non-smoker or quit >12 months ago). Drinking status was divided into 'yes' (current drinking <one standard servings/day,<two standard servings/day, two to four standard servings/day, ≥five standard servings/day) and 'no' (never drank, drank in the past). A standard serving was defined as 15 g of ethanol. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured twice using a mercury sphygmomanometer with the subject in a seated position. If the difference between the two measurements exceeded 5 mm Hg, an additional reading was taken, and the average of the three readings was used. Hypertension was defined as having a history of hypertension, exhibiting an SBP ≥140 mm Hg or a DBP ≥90 mm Hg or using antihypertensive medications. The definition of diabetes mellitus was a fasting glucose level ≥7.0 mmol/L (126 mg/dL), current treatment with insulin/oral hypoglycaemic agents or a history of diabetes mellitus. Dyslipidaemia was defined as a history of hyperlipidaemia, a total blood cholesterol level ≥220 mg/dL, a triglyceride level ≥150 mg/dL or use of anti-hyperlipidaemic medications. All measures in this cross-sectional study reflected the current values as of data collection.

Statistical analysis

We first compared the characteristics of individuals according to their earthquake and bereavement experiences (no earthquake experience, earthquake experience without bereavement and earthquake experience with bereavement) using the X^2 test for categorical variables and one-way analysis of variance or the Kruskal–Wallis test for continuous variables.

We used logistic regression to examine the association between earthquake experience and current depression, with 'no earthquake experience' as the reference group. Four multivariate models were fitted as follows: Model 1 was the unadjusted model. Model 2 was adjusted for age at the time of the earthquake and gender. Model 3 was further adjusted for smoking status, drinking status, education, income and residence in Tangshan 1 to 2 years after the earthquake. Model 4 was further adjusted for hypertension, diabetes and dyslipidaemia.

We also used multiple logistic regression to examine the association stratified by gender and age at the time of the earthquake. To evaluate whether the effect of the earthquake on depression would be modified by gender

and/or age at the time of the earthquake, we tested the statistical significance of earthquake × gender and earthquake × age at the time of the earthquake as interaction effects in a multiple-adjustment logistic model by applying a post-estimation Wald test to obtain an omnibus p value for the interactions between earthquake categories and depression.

All statistical tests were two-sided, and results with a p value<0.05 were considered statistically significant. The analyses were performed in SAS V.9.4 (SAS Institute Inc, Cary, North Carolina, USA).

Patient and public involvement

Patients and the public were not involved in the development of the research question or outcome measures, study design, recruitment or conduct of the study. The results will be disseminated to study participants through annual information events.

RESULTS

Characteristics of the study participants

The characteristics of the participants according to earthquake and bereavement experiences are shown in table 1. In total, 5024 participants were included in this study; the participants were 50.2% male and ranged in age from 37 to 82 years at the time of data collection. Among all participants, 543 (10.8%) individuals experienced the earthquake without bereavement, and 98 (2.0%) participants lost relatives. The individuals who experienced the earthquake with or without bereavement were younger and were more likely to have lived in Tangshan 1 to 2 years after the earthquake than those who had not experienced the earthquake (12.1±9.0, 13.1±9.1 and 14.8±9.2 years, respectively, for age; 86.7%, 79.4% and 1%, respectively, for residence). No differences were found in gender, smoking status, drinking status, education, income, hypertension, diabetes or dyslipidaemia. A higher incidence of depression was observed in the bereaved and non-bereaved earthquake survivors (12.2% (12/98) and 7.2% (39/543), respectively) than in those without earthquake experience (4.9% (215/4383)).

Association between earthquake experience and depression

ORs and 95% CIs for the association between earthquake experience and depression are presented in table 2. The risk of depression in the bereaved subgroup was 2.82 times (OR 2.82, 95% CI 1.24 to 6.39) higher than that in the group with no earthquake experience after adjusting for gender, age at the time of the earthquake, smoking status, drinking status, education, income, residence in Tangshan 1 to 2 years after the earthquake, hypertension, diabetes and dyslipidaemia. However, no statistically significant association was found in the non-bereaved group.

Table 1 Population characteristics according to earthquake experience

Characteristics	Overall	No experience (n=4383)	Experience without bereavement (n=543)	Experience with bereavement (n=98)	P value
Men, n (%)	2524 (50.2)	2210 (50.4)	276 (50.8)	38 (38.8)	0.071
Age at the time of the earthquake, mean (SD)	14.6±9.2	14.8±9.2	13.1±9.1	12.1±9.0	<0.001
≤6	1063 (21.2)	880 (20.08)	146 (26.89)	37 (37.76)	<0.001
6–18	2053 (40.9)	1796 (40.98)	226 (41.62)	31 (31.63)	
≥18	1908 (38.0)	1707 (38.95)	171 (31.49)	30 (30.61)	
Smoking, n (%)	1286 (25.6)	1136 (25.9)	132 (24.3)	18 (18.4)	0.182
Drinking, n (%)	1578 (31.4)	1364 (31.1)	186 (34.3)	28 (28.6)	0.276
Education, n (%)					0.689
Illiteracy/primary	318 (6.3)	279 (6.4)	31 (5.7)	8 (8.2)	
Middle school/high school	2704 (53.8)	2370 (54.1)	282 (51.9)	52 (53.1)	
University or above	2002 (39.9)	1734 (39.6)	230 (42.4)	38 (38.8)	
Income, n (%)					0.127
≤3000	2415 (48.1)	2087 (47.6)	270 (49.7)	58 (59.2)	
3001–5000	2278 (45.3)	2002 (45.7)	243 (44.8)	33 (33.7)	
>5000	331 (6.6)	294 (6.7)	30 (5.5)	7 (7.1)	
Residence in Tangshan 1–2 years after the earthquake, n (%)	561 (11.2)	45 (1.0)	431 (79.4)	85 (86.7)	<0.001
Hypertension, n (%)	2158 (43.0)	1872 (42.7)	237 (43.7)	45 (45.9)	0.463
Diabetes, n (%)	550 (11.0)	497 (11.3)	43 (7.9)	10 (10.2)	0.054
Dyslipidaemia, n (%)	3102 (61.7)	2696 (61.5)	343 (63.2)	63 (64.3)	0.659
Depression, n (%)	266 (5.3)	215 (4.9)	39 (7.2)	12 (12.2)	0.001

Subgroup analysis by gender and age as of the earthquake

In the models stratified by gender, the female subjects in both the bereaved (OR 3.51, 95% CI 1.21 to 10.16) and non-bereaved (OR 3.07, 95% CI 1.44 to 6.56) subgroups had an increased risk of depression. In contrast, no significant association was found between earthquake experience and the risk of depression among male subjects in either the bereaved (OR 2.09, 95% CI 0.58 to 7.61) or the non-bereaved (OR 0.84, 95% CI 0.32 to 2.20) subgroup.

In the models stratified by age at the time of the earthquake, we found a statistically significant association in individuals over 18 years old whether they had lost relatives in the earthquake (OR 13.16, 95% CI 3.08 to 56.3) or not (OR 3.39, 95% CI 1.31 to 8.87). No statistically significant association was found in survivors under 6 years old whether they had been bereaved (OR 1.65, 95% CI 0.42 to 6.49) or not (OR 1.09, 95% CI 0.36 to 3.27), and there was also no significant association in survivors aged

Table 2 ORs for the association between earthquake experience and depression

	No earthquake experience (n=4383, 87.2%)	Experience without bereavement (n=543, 10.8%)	Experience with bereavement (n=98, 2.0%)
Model 1	1	1.42 (0.99–2.20)	2.46 (1.32–4.59)
Model 2	1	1.43 (1.01–2.04)	2.50 (1.34–4.68)
Model 3	1	1.61 (0.88–2.95)	2.88 (1.26–6.57)
Model 4	1	1.69 (0.93–3.08)	2.82 (1.24–6.39)

Model 1 refers to the unadjusted model.
Model 2 refers to the model adjusted for gender and age at the time of the earthquake.
Model 3 refers to the model adjusted for gender, age at the time of the earthquake, smoking status, drinking status, education, income and residence in Tangshan 1 to 2 years after the earthquake.
Model 4 refers to the model adjusted for gender, age at the time of the earthquake, smoking status, drinking status, education, income, residence in Tangshan 1 to 2 years after the earthquake, hypertension, diabetes and dyslipidaemia.
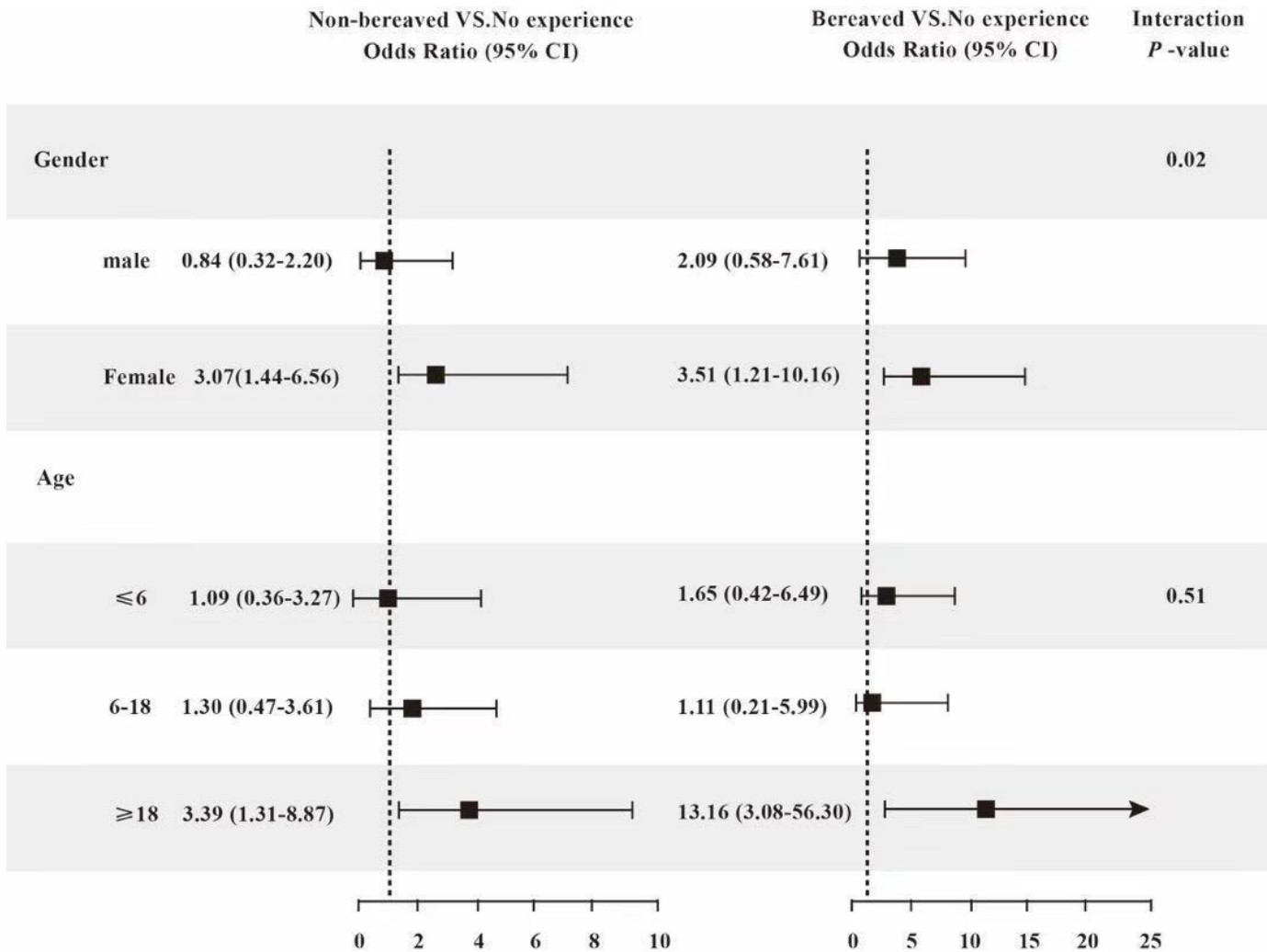
Figure 1 OR of depression given earthquake experience, stratified by gender and age at the time of the earthquake. Groups stratified by gender, adjusted for age at the time of the earthquake, smoking status, drinking status, education, income, residence in Tangshan 1 to 2 years after the earthquake, hypertension, diabetes and dyslipidaemia. Groups stratified by age at the time of the earthquake, adjusted for gender, smoking status, drinking status, education, income, residence in Tangshan 1 to 2 years after the earthquake, hypertension, diabetes and dyslipidaemia.

between 6 and 18 years whether they had lost relatives (OR 1.11, 95% CI 0.21 to 5.99) or not (OR 1.30, 95% CI 0.47 to 3.61).In addition, we found a statistically significant interaction between gender and depression (p for interaction=0.02) but no significant interaction between age at the time of the earthquake and depression (p for interaction=0.51) (figure 1).

DISCUSSION
In this community-based study, we observed that, even after 37 years, earthquake survivors had a higher risk of depression than those who had not experienced the earthquake. In addition, long-term effects of the earthquake on depression were found among bereaved survivors, women and individuals over 18 years old. This study is the first to investigate the association between earthquake experience and depression 37 years after an earthquake.

Evidence shows that traumatic experiences in childhood and adolescence may have a determining effect on brain structural development, sympathetic nervous system responsivity and the hypothalamic–pituitary–adrenal axis, especially in younger children (preschool) and school-age children (late childhood and early adolescence), resulting in a large stress response and some psychological problems.[18] Therefore, we classified the participants into age categories of 0 to 6, 6 to 18 and older than 18 years to investigate the long-term impact of disaster on mental health during different stages of life. However, statistically significant associations were found only in individuals over 18 years of age. One explanation is that different ages have different needs for social networks. Social networking is associated with the onset of depression.[34] Children's and adolescents' social needs are met by parental care and family.[35] Adults, in contrast, need support from social interaction in the

neighbourhood, the communities and the work place in addition to family support.[36] The advent of the earthquake destroyed the previously stable social networks and economic foundation of the community. Social-network destruction may lead to some mental health disorders. Additionally, survivors under 18 years old recover from disaster more easily than older survivors do. Insensitivity to the nature and meaning of disaster trauma[37] and access to mental health intervention in the early post-disaster stages[38] may contribute to recovery from psychological problems among child and adolescent survivors.

With regard to gender, we found a significant association between earthquake experience and depression in women but not in men. Similar results have been found in several previous studies of disaster, indicating that women may be at a higher risk of depression than men when they experienced disasters including large earthquake.[13 19] Differences in physiology, personality, social role and rumination between women and men might result in this gender difference in the association between depression and disaster.[39–43] The exact causal factors leading to gender differences in long-term effects of earthquakes remains a big challenge for future researches.

Consistent with our findings, a longitudinal study on the Alexander Kielland oil platform collapse shows that survivors have a higher risk of depression than non-exposed individuals 27 years after the disaster.[15] Similar results are observed in another longitudinal study with 10 years of follow-up, which indicates that survivors of the Piper Alpha oil platform disaster show a long-lasting increase in mental health problems compared with non-exposed individuals.[16] In contrast, two studies indicate that disaster has little long-term effect on depression.[13 14] The inconsistency of the results may be explained by the severity of the disaster. The Tangshan earthquake caused more damage than the Buffalo Creek dam collapse or the Australian bushfire disaster. The earthquake reduced Tangshan to ruins in a few minutes, with approximately 85% of the buildings collapsed and at least 400 000 casualties.[20 44] The earthquake afflicted the survivors with not only the loss of their homes but also, more importantly, the tension and fear brought by the disaster itself, the loss of loved ones, the complete destruction of social networks and a sense of despair.[45 46] During the long-term urban reconstruction process, all these effects of the disaster might lead to long-term adverse psychological effects on the survivors. In addition, the Tangshan earthquake broke out at the end of the decade of the Cultural Revolution. The consequences of the Cultural Revolution, which include a fragile economic foundation, low economic compensation, lack of societal acknowledgement and destruction of the healthcare service network, may have delayed recovery.

The long-term effect of disaster on depression seems to depend on traumatic experience. In our study, a statistically significant association between earthquake experience and depression was observed in bereaved survivors but not in non-bereaved survivors 37 years after the earthquake. This finding was consistent with a longitudinal study carried out in Italy showing that exposure to loss and damage during an earthquake confers an additional risk of negative psychological consequences above and beyond living in the earthquake zone.[10] Similarly, a longitudinal study 14 years after MS Estonia Disaster indicated that non-bereaved survivors recovered from their post-traumatic stress reactions, while little change was found over that period in the reaction of the bereaved.[12] Traumatic bereavement may be associated with increased severity of long-term post-traumatic stress reactions after disasters,[47] which is considered to be involved in the onset of depression.[4]

Several plausible explanations may link earthquake exposure to the prevalence of depressive symptoms. Earthquakes can cause tremendous, immediate damage to the environment and even lead to adverse life events such as the death of a family member and related events, thus exerting negative effects on individuals' emotions and resulting in post-traumatic stress disorder (PTSD) after the disaster.[4 12] PTSD, as a frequent comorbidity of depression,[48 49] may persist for decades following disaster.[50–52] These findings suggest that traumatic bereavement might be a common mediating mechanism of both depression and PTSD. The pain of loss in survivors may have neurobiological effects on several brain areas (the frontolimbic and striatal areas).[47 53] These areas and the functional connectivity within the fronto-striato-thalamic and default-mode networks have been found to be correlated with the progression of mental health problems and may play important roles in adaptation to trauma.[4 54] The trauma caused by disasters has a variety of mechanisms. Whether PTSD symptoms further transform into depression or other mental illnesses in the long-term will require further exploration.

Gender, age at the time of the earthquake, education, income, smoking, drinking, living in the affected area after a disaster, hypertension, diabetes and dyslipidaemia were controlled in the multiple variable analysis. To avoid over fitting, we used four models to adjust confounding variables step by step. The resulting ORs reflected minor changes in the four models, suggesting that earthquake experience may be an independent risk factor for the occurrence of depression.

Our study has a few limitations. First, substantial time has passed since the earthquake occurred, and we were unable to control for every event or factor. For example, we did not consider other traumatic events, such as traffic accidents, adverse childhood experiences, other bereavement or current psychological stressors, which could have confounded the observed associations. Additionally, the sample was not representative of all survivors of the Tangshan earthquake. We did not include survivors who had died in the past 37 years. Premature death may be related to depression and disease. Meanwhile, in our sample, nearly 20% of the survivors did not live in the earthquake zone 1 to 2 years after the earthquake.

These people left the painful environment and may have worked or attended school elsewhere for several years, which may have largely relieved psychological stress and alleviated the symptoms of depression. Therefore, the potential impacts of the earthquake on depression may have been underestimated. Third, whether the subjects were taking antidepressants was unknown. Fourth, the cross-sectional design of this study precludes causal inferences. Finally, depression was assessed only once during the study; therefore, we could not exclude the possibility of reverse causality.

The results of our study are very relevant to future research on depression among disaster survivors. For instance, survivors of earthquakes in Japan, Haiti and China were all affected by high rates of depression in the short term.[55–58] Although the timing and severity of the disasters, the ethnicity of the affected population and the living environment of the survivors are different, the stressors caused by disasters are similar. Strengthening community social cohesion can facilitate recovery from disaster trauma.[59 60] Clinicians and policymakers in public health should direct additional early social support towards high-risk survivors of disasters, a measure that may reduce the incidence of mental health problems, including depression, in disaster zones,[61] even long after the disaster has passed.

CONCLUSIONS

Thirty-seven years after the disaster, earthquake experience was associated with depression among bereaved survivors, women and individuals over 18 years old at the time of the earthquake. Our study provides evidence supporting the hypothesis that the effect of an earthquake on depression persists for at least 37 years.

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