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Association between Earthquake and Depression 37 Years after the Tangshan Earthquake: a Community-based Study

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3 **Association between Earthquake and Depression 37 Years after the Tangshan Earthquake: a**
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6 **Community-based Study**

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ABSTRACT

Objective To investigate the association between a major earthquake, the Tangshan earthquake, and the risk of depression over 37 years.

Design and setting Prospective, population-based cohort study conducted in Tangshan from 2013 to 2014.

Participants This general community sample included 5024 participants who were born before July 28, 1976, when the Tangshan earthquake occurred, with available data on their earthquake experiences and depression 37 years after the earthquake.

Outcomes and variables ORs for having earthquake experience with or without bereavement (relative to no earthquake experience) obtained by multinomial logistic regression, adjusted for gender, age during the earthquake, marital status, smoking, drinking, education, income, residence in Tangshan 1-2 years after the earthquake, hypertension, diabetes, and dyslipidemia.

Results Of the 5024 participants, 641 experienced the Tangshan earthquake, and 98 experienced bereavement. Participants who experienced the earthquake (with or without bereavement) were 83% (odds ratios (OR) 1.83, 95% confidence interval (CI) 1.02-3.29) more likely to develop depression after 37 years. Those who lost relatives after the earthquake were nearly 3 times (OR 2.82, 95% CI 1.24-6.39) as likely to develop depression as those who did not experience the earthquake. The association was more pronounced for women: women who experienced the earthquake with or without bereavement were more than 3 times as likely to develop depression, whereas no significant association was found for men (interaction by gender $p=0.02$).

Conclusions The Tangshan earthquake is associated with an increased long-term risk of depression in survivors who experienced bereavement, particularly women. Our findings suggest a need for long-term surveillance of depression and early intervention among survivors of major earthquakes.

Strengths and limitations of this study

- This is the first study to show long-term risk of depression 37 years following an earthquake.
- Participants are stratified by gender and age at the earthquake, which is necessary for clinicians and policymakers to identify high-risk populations for long-term prevention of depression after an earthquake.
- We were unable to control for every event or factor during the follow-up.
- Whether the subjects were taking antidepressants was unknown.
- Depression was assessed only once during the study.

INTRODUCTION

The prevalence of depression is increasing worldwide[1]. According to the World Health Organization, depression will be a major reason for disability around the world by 2030[2]. Therefore, it is critical to identify populations at high risk of depression.

In recent years, an increasing number of studies have suggested that earthquakes are closely related to the development of mental illnesses, including post-traumatic stress disorder (PTSD), depression and anxiety[3-6]. In particular, several studies have indicated an increased prevalence of depression among individuals who survived a major earthquake[7, 8]. Moreover, survivors who lost relatives and vulnerable individuals, such as women and the elderly, during the earthquake were particularly affected[9, 10]. However, these studies mainly examined the effects of earthquakes on depression in the short-term. It was unclear whether the increased risk of depression persisted over a long period following the earthquakes. Depression is chronic and debilitating[11], and the long-term effects of an earthquake on depression may result in chronic psychological disorders[12, 13]. The likelihood of developing a long-term psychiatric disorder may be reduced if effective treatment can be implemented among the population that needs it most before the disorder becomes entrenched[14].

These long-term effects are difficult to establish due to the scarcity of information concerning the present health status of survivors, which is due to the high cost and difficulty of tracking individuals over time[15]. In China, the Jidong Cohort, located in Tangshan, provides a suitable setting for studying the long-term effect of an earthquake on depression. The Tangshan earthquake, which

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3 occurred in 1976, had a magnitude of 7.8 on the Richter scale[16]. Over the past 37 years, numerous
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5 studies have examined the effects of the Tangshan earthquake on physical health outcomes. These
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7 studies suggested an increased risk of diabetes, cardiovascular disease, and elevated levels of uric acid
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9 among survivors of the Tangshan earthquake even more than 30 years later[17-19]. However, no study
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11 to date has examined the long-term effect of Tangshan earthquake on the risk of depression. Given the
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13 high morbidity and additional complications of depression, it is important to identify the high-risk
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15 group to provide evidence for psychological intervention in the vulnerable group.
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24 The present study aimed to examine whether the Tangshan earthquake increased the rate of depression
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26 37 years later and to study whether those who lost relatives during the earthquake were particularly
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28 affected. We also examined whether the association between the earthquake and depression varies by
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30 gender and age at the time of the earthquake.
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36 **MATERIALS AND METHODS**

37 **Study participants**

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39 We used data obtained from the Jidong Cohort, an ongoing community-based study[20]. Jidong is
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41 located in the Caofeidian district of Tangshan City, which is 60 km from the epicenter of the Tangshan
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43 earthquake. From July 2013 to August 2014, a total of 9078 residents of Jidong were recruited for the
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45 study, completed a standardized questionnaire, and underwent physical examinations and laboratory
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47 assessments. We included 5024 participants from the Jidong Cohort; all were born before July 28,
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49 1976, when the earthquake occurred, and provided baseline information on their experiences with the
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3 earthquake. This study was conducted in accordance with the guidelines in the Helsinki Declaration
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6 and approved by the Ethics Committee of Jidong Oilfield Staff Hospital. All participants provided
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9 written informed consent.

10 11 12 13 **Assessment of the earthquake experience**

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16 During the baseline visit, participants reported their earthquake experience and related bereavement
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18 using a standardized questionnaire. Participants were asked “Were you in the Tangshan earthquake
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20 area in 1976?” and “Did you lose any relatives in the earthquake?”. Participants who confirmed that
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22 they had experienced the earthquake were placed into one of 3 groups: no earthquake experience;
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24 earthquake experience without bereavement; and earthquake experience with bereavement.
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31 **Assessment of depression**

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34 Depressive symptoms were assessed using the Center for Epidemiological Studies Depression Scale
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36 (CES-D), which was initially developed by the United States National Institute of Mental Health in
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38 1977[21]. The Chinese version of the CES-D was translated by two psychiatrists on the basis of the
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40 international standard version of the CES-D questionnaire in 1985[22] and was specifically designed
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42 to screen for depression[23]. All investigators attended a 3-day training course and were licensed
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44 before conducting CES-D interviews. The highest possible score on the CES-D scale was 60, and a
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46 score of 16 or higher was used to define clinically meaningful depressive symptoms.
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52 **Assessment of potential covariates**

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54 All demographic and behavioral variables were collected using questionnaires, which were
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3 administered by well-trained research nurses. Potential confounding variables included gender, age at
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6 time of earthquake, smoking, drinking, education, income, residence in Tangshan 1-2 years after the
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9 earthquake, hypertension, diabetes, and dyslipidemia. Age at the time of the earthquake was defined as
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11 a continuous variable. The average monthly income of each family member was categorized as
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13 “<¥3000”, “¥3000–5000” or “>¥5,000”. Educational level was categorized as “illiterate or primary
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15 school,” “middle school or high school,” and “university or above.” Possible responses to questions on
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17 smoking status, drinking status were “yes” and “no.” Systolic blood pressure (SBP) and diastolic
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19 blood pressure (DBP) were measured twice with the subject in a seated position using a mercury
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21 sphygmomanometer. If the difference between the two measurements exceeded 5 mm Hg, an
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23 additional reading was taken, and the average of the three readings was used. Hypertension was
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25 defined as having a history of hypertension, exhibiting an SBP ≥ 140 mm Hg or a DPB ≥ 90 mm Hg, or
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27 using antihypertensive medications. Diabetes mellitus was defined as a fasting glucose level ≥ 7.0
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29 mmol/l (126 mg/dl), any use of glucose-lowering drugs, or any self-reported history of diabetes mellitus.
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Patients and public involvement

Patients and public did not involve in the design of the study. However, Participants signed written informed consent. They actively cooperated with the researcher to complete the collection of questionnaire information and were willing to provide support for further use of data.

Statistical analysis

We first compared the baseline characteristics of individuals according to their earthquake and bereavement experiences (no earthquake experience, earthquake experience without bereavement, and earthquake experience with bereavement) using the chi-square test for categorical variables and one-way ANOVA or the Kruskal Wallis test for continuous variables.

We used logistic regression to examine the association between earthquake experience and depression and obtained odds ratios of the development of clinically meaningful depressive symptoms with "no earthquake experience" as the reference group. We adjusted for a number of potential confounders, including gender, age during the earthquake, smoking, drinking, education, income, residence in Tangshan 1-2 years after the earthquake, hypertension, diabetes, and dyslipidemia. To determine whether the association between earthquake and depression varied by gender and age during the earthquake, we also performed a subgroup analysis using these variables and tested for significance of the interaction terms.

All statistical tests were 2-sided, and results with a P-value<0.05 was considered statistically significant. Analyses were implemented in SAS version 9.4 (SAS Institute Inc., Cary, NC, USA).

RESULTS

Baseline characteristics

Baseline characteristics of earthquake and bereavement experiences are shown in Table 1. In total, 543 (10.8%) out of 5024 individuals experienced the earthquake without bereavement, and 98 (2.0%)

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3 participants lost relatives. Individuals who experienced earthquakes, with or without bereavement,
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6 were younger (14.8 ± 9.2 , 13.1 ± 9.1 vs. 14.8 ± 9.2) and were more likely to have lived in Tangshan 1-2
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8 years after the earthquake (86.7%, 79.4% vs. 1%) than those who had not experienced earthquakes.
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11 There was no difference in gender, smoking, drinking, education, income, hypertension, diabetes or
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13 dyslipidemia. Compared to those without earthquake experience, there was a higher incidence of
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15 depression in the bereaved and non-bereaved groups (12.2% (39/543) and 7.2% (12/98)) (Figure 1).
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21 **Association of earthquake experience with depression**

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23 Odds ratios (ORs) with 95% confidence intervals (CIs) between earthquake experience and depression
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25 are presented in Table 2. Earthquake experience was significantly associated with depression. The
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27 adjusted OR of the group that had earthquake experience was 1.83 (OR, 1.83; 95% CI, 1.02-3.29) with
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29 respect to that of the group with no earthquake experience. However, when the group with earthquake
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31 experience was divided into bereaved and non-bereaved subgroups, a higher risk of depression was
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33 found only in the bereaved subgroup. As shown in Table 2, the risk of depression in the bereaved
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35 subgroup was 2.82 times (OR, 2.82; 95% CI, 1.24-6.39) that in the group with no earthquake
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37 experience.
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47 **Subgroup analysis by gender and age during the earthquake**

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49 In models stratified by gender, both the bereaved (OR, 3.07; 95% CI, 1.44-6.56) and non-bereaved
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51 (OR, 3.51; 95% CI, 1.21-10.16) subgroups were associated with increased risk of depression in female
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53 subjects. There were significant associations between the earthquake and depression in females but not
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3 in males (P for interaction=0.02). In models stratified by age at the time of the earthquake, we did not
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6 identify any significant interaction between age during the earthquake and depression (P for
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8 interaction=0.51) (Figure 2).
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10 11 **Discussion**

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13 To our knowledge, this is the first study to prove that earthquake survivors have a higher risk of
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15 developing depressive symptoms than those who did not experience an earthquake, even 37 years
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17 later.
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23 These findings extend the current literature, which largely focuses on short-term follow-up with
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25 earthquake survivors. The short-term effects of a disaster on mental health are believed to result from
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27 acute stressors, such as frightening and terrible conditions in the immediate aftermath of traumatic
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29 exposure[7, 24]. In contrast to short-term effects, the long-term effects following different
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31 pathogeneses are referred to as chronic stressors. In most cases, an acute stressor increases the adverse
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33 psychological reaction in the short term but abates in the ensuing period, whereas a chronic stressor
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35 might result in long-standing psychological disorders[24, 25].
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45 Our study observed the long-term effects of an earthquake on depression among individuals who
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47 experienced bereavement, suggesting that a loss of family during the earthquake could lead to chronic
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49 stress. Our findings were similar to those obtained in a longitudinal study of an earthquake in Italy
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51 with a 7-year follow-up period, which reported that survivors who were exposed to loss and damage
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53 had an increased risk of negative psychological consequences than those who merely lived in the
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3 earthquake zone[26]. These findings demonstrated that the adverse consequences induced by an
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6 earthquake are long-term risk factors that increase the prevalence of mental disorders.
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11 Many studies have also assessed specific population groups, particularly women and youth, who are
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13 more vulnerable to earthquakes. Several studies of earthquakes have shown that these vulnerable
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15 populations might be at higher risk of depression[10, 27-29]. Similar results were obtained in the
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17 subgroup analysis of gender in our study, which found that female survivors with or without
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19 bereavement were more affected by an earthquake even 37 years later. However, in the subgroup
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21 analysis of age, the interaction between age during the earthquake and depression was not significant
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23 in the current study, which was probably due to the small size of the subgroups.
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31 The results of our study are very relevant to future research on depression in earthquake survivors. For
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33 instance, survivors of earthquakes in Japan, Haiti, and China were all affected by high rates of
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35 depression in the short term. Although these studies varied in ethnicity, severity of earthquake
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37 exposure, consequent degree of damage and demographic characteristics, they had similar general
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39 characteristics and traumatic experiences, which could have contributed to long-lasting adverse
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41 psychological outcomes.
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49 Our study had a few limitations. First, the study was conducted over a long period, and we were
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51 unable to control for every event or factor during the follow-up. For example, we did not consider
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53 other traumatic events, such as traffic accidents, economic crises or floods, which might also result in
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3 depression. Additionally, whether the subjects were taking antidepressants was unknown. Finally,
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6 depression was assessed only once during the study, and therefore, we could not exclude the
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8 possibility of reverse causality. However, it was unlikely that people who experienced an earthquake
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10 were more likely to be depressed prior to the earthquake.
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13 This study suggests that the effect of an earthquake on depression remains for 37 years and helps
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15 identify individuals who are prone to depression. It should be noted that depression can cause a series
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17 of physiological disorders, exacerbate diseases and disabilities, and even result in suicide[11, 30, 31].
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19 Therefore, long-term depression could result in higher prevalence of physical morbidity and mortality.
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21 Clinicians and policymakers in public health should pay more attention to survivors who are likely to
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23 develop long-term depression because they may obtain benefit from early intervention policies and
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25 strategies.
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34 **Conclusions**

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36 In summary, having experienced an earthquake increases the risk of depression and has long-lasting
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38 effects on depression in bereaved survivors, particularly women, after the earthquake. Future studies
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40 are required to examine the underlying mechanisms of the association between an earthquake and
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42 development of depression in the long term. Survivors of major earthquakes need to be monitored
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44 carefully and continuously for mental health symptoms. Early intervention should be considered to
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46 prevent the development of depression in these populations.
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Contributors All authors have been involved from the beginning in all phase of the study. XG, YZ and HPH designed the study. XG and YL analyzed the data and prepared the manuscript. JCY, QHC and BG critiqued the manuscript for important intellectual content. XG and YCG conducted the statistical analysis. All authors have read and approved the final version of this manuscript.

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Competing interests None declared.

Patient consent Obtained

Ethics approval Ethics Committee of Jidong Oilfield Staff Hospital

Provenance and peer review Not commissioned; externally peer reviewed

Data sharing statement The data used or analyzed during the current study are available from the corresponding author on reasonable request.

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TABLE 1 Baseline characteristics according to earthquake experience

Characteristic	Overall	No experience (n=4383)	Experience without bereavement (n= 543)	Experience with bereavement (n= 98)	<i>P Value</i>
Men, No. (%)	2524(50.2)	2210(50.4)	276(50.8)	38(38.8)	.07
Age at the time of the earthquake, mean (SD), y	14.6(9.2)	14.8(9.2)	13.1(9.1)	12.1(9.0)	<.001
Smoking, No. (%)	1286(25.6)	1136(25.9)	132(24.3)	18(18.4)	.18
Drinking, No. (%)	1578(31.4)	1364(31.1)	186(34.3)	28(28.6)	.28
Education, No. (%)					.69
Illiterate/primary school	318(6.3)	279(6.4)	31(5.7)	8(8.2)	
Middle/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, No. (%)					.13
<=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)	
Characteristic	Overall	No experience	Experience without	Experience with	<i>P Value</i>

		(n=4383)	bereavement (n= 543)	bereavement (n= 98)	
Residence in Tangshan 1-2 years after the earthquake, No. (%)	561(11.2)	45(1.0)	431(79.4)	85(86.7)	<.001
Hypertension, No. (%)	2158(43.0)	1872(42.7)	237(43.7)	45(45.9)	.46
Diabetes, No. (%)	550(11.0)	497(11.3)	43(7.9)	10(10.2)	.05
Dyslipidemia, No. (%)	3102(61.7)	2696(61.5)	343(63.2)	63(64.3)	.66
Depression, No. (%)	266(5.3)	215(4.9)	39(7.2)	12(12.2)	<.001

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Table 2. Association of Earthquake Experience with Depression

Characteristic	Odds Ratio (95% CI)			
	No experience (n= 4383)	No bereavement (n=543)	Bereavement (n=98)	Experience (n=641)
n (%)	87.2	10.8	2.0	12.8
Unadjusted Models	1	1.42(0.99-2.20)	2.46(1.32-4.59)	1.58(1.14-2.17)
Adjusted Models*	1	1.69(0.93-3.08)	2.82(1.24-6.39)	1.83(1.02-3.29)

* Adjusted ORs are adjusted for gender, age during the earthquake, smoking, drinking, education, income, residence in Tangshan 1-2 years after the earthquake, hypertension, diabetes, and dyslipidemia

Figure 1. Depression rates for four categories of earthquake experience

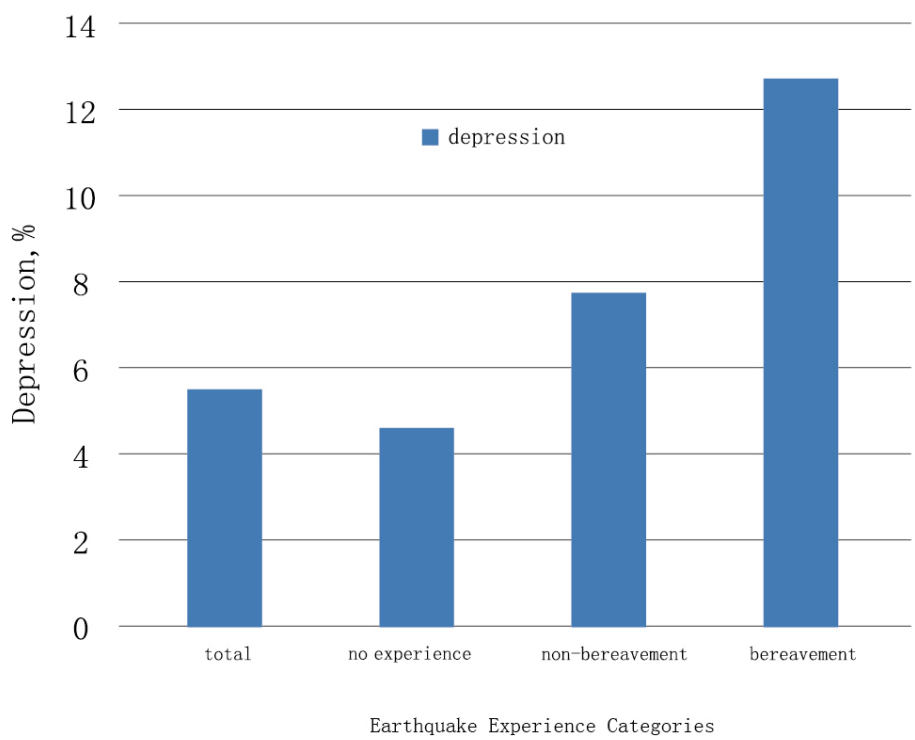
Figure 2. Adjusted ORs of earthquake experience for depression stratified by gender and age during the Tangshan earthquake (adjusted for gender, age during the earthquake, marital status, smoking, drinking, education, income, residence in Tangshan 1-2 years after the earthquake, hypertension, diabetes, and dyslipidemia).

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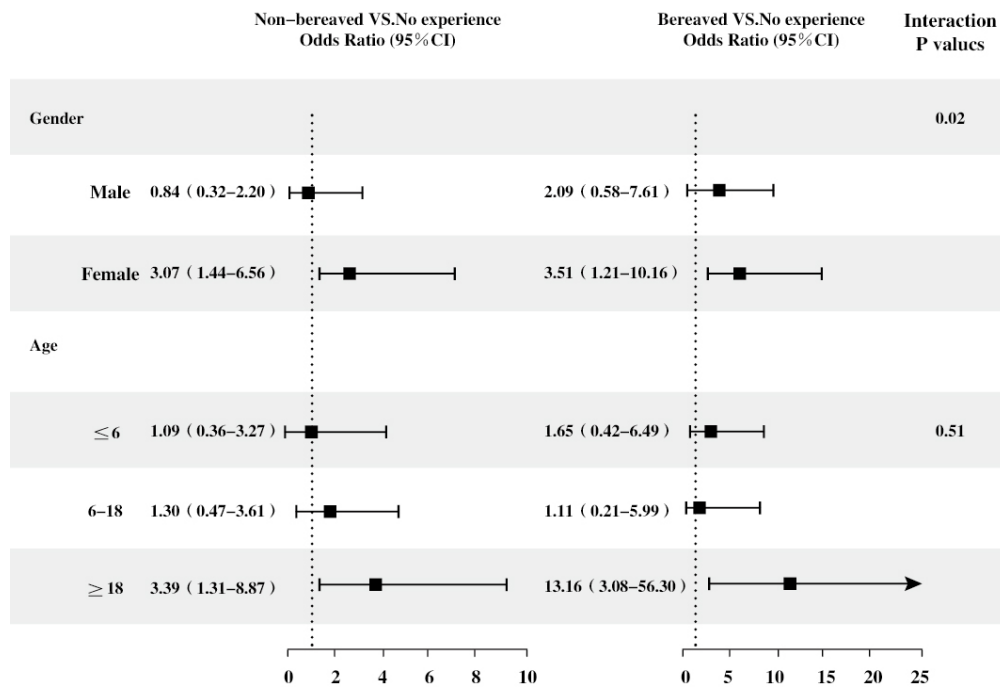
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Depression rates for four categories of earthquake experience

90x90mm (300 x 300 DPI)



Adjusted ORs of earthquake experience for depression stratified by gender and age during the Tangshan earthquake

90x90mm (300 x 300 DPI)

BMJ Open

The Association between Earthquake Experience and Depression 37 Years after the Tangshan Earthquake: A Cross-sectional Study

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Manuscripts

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3 1 **The Association between Earthquake Experience and Depression 37 Years after**
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5 2 **the Tangshan Earthquake: A Cross-sectional Study**

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3 43 **ABSTRACT**
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5 44 **Objective** To investigate the association between the Tangshan earthquake and the
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8 45 risk of depression after 37 years.
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10 46 **Design and setting** A cross-sectional study conducted in Tangshan from 2013 to
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12 47 2014.
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14 48 **Participants** The sample included 5024 participants born before July 28, 1976, when
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16
17 49 the Tangshan earthquake occurred, with available data on their earthquake
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19 50 experiences and depression 37 years after the earthquake.
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21 51 **Outcomes and variables** The outcome was depression measured using the Center for
22
23 52 Epidemiological Study and Depression Scale (CES-D). The independent variable was
24
25 53 earthquake experience, with 3 groups: no earthquake experience, earthquake
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27 54 experience without bereavement, and earthquake experience with bereavement.
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29 55 Multivariable logistic analysis was used to evaluate the association between
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31 56 earthquake experience and depression after adjusting for gender, age at the time of the
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33 57 earthquake, smoking status, drinking status, education, income, residence in Tangshan
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35 58 1-2 years after the earthquake, hypertension, diabetes, and dyslipidemia.
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39 59 **Results** Of the 5024 participants, 641 experienced the Tangshan earthquake, and 98
40
41 60 experienced bereavement. Participants who experienced the earthquake (with or
42
43 61 without bereavement) had higher prevalence of depression than those without
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45 62 earthquake experience (12.2%, 7.2% vs. 4.9%, respectively), 37 years after the
46
47 63 earthquake. Survivors who lost relatives during the earthquake were nearly 3-times
48
49 64 (OR 2.82, 95% CI 1.24-6.39) as likely to have depression as those who did not
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51 65 experience the earthquake. A statistically significant association between the
52
53 66 earthquake and depression was found in women, but not in men, and in individuals
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55 67 over 18 years of age.
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3 68 **Conclusions** Earthquake experience had long-lasting effects on depression among
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5 69 bereaved survivors, women and individuals over 18 years old 37 years later.
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For peer review only

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3 72 **Strengths and limitations of this study**
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5 73 ● The study investigated the long-term risk of depression as long as 37 years after a
6
7 74 major earthquake.

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10 75 ● Participants were stratified by gender and age at the time of the earthquake.

11
12 76 ● We were unable to control for every event or factor, such as adverse childhood
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14 77 experiences, other bereavement or current psychological stressors.

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17 78 ● Individuals who experienced the Tangshan earthquake did not include those who
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19 79 died.
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80 INTRODUCTION

81 Depression is predicted to be a major reason for disability around the world by 2030
82 according to the World Health Organization¹. In addition, the chronic and debilitating
83 nature of depression complicates the prognosis of chronic diseases, aggravates
84 diseases and even leads to suicide²⁻⁴. Evidence shows that depression is related to
85 demographic characteristics, living habits, education, income, and health status⁵⁻⁷.
86 Participants exposed to disasters at early life stage are of higher risk of depression,
87 independent to age, gender, income, education and other confounders in the short
88 term (1-4 years)⁸⁻¹⁰. Meanwhile, studies report that some survivors have
89 psychological problems in the immediate aftermath of disaster trauma, most of these
90 reactions abate over time, and only a minority of survivors develop a long-standing
91 disorder^{11 12}. Therefore, long-term evidence is essential to evaluate the effects of
92 disaster on depression.

93 Findings regarding the long-term impact of disasters on mental health have been
94 mixed. Several studies have reported no differences^{13 14}, but others have revealed
95 more psychological problems in exposed individuals compared with non-exposed
96 individuals for more than a decade after disasters^{10 15 16}. Moreover, evidences show
97 that such effects are increased if survivors suffer from bereavement^{10 12}. Overall
98 levels of psychological symptoms may be associated with different age stages^{17 18},
99 and women show more psychological symptoms than men^{13 19}. However, in these
100 studies, the samples were relative small and not representative of the affected
101 population. One study with a sample of 529 people followed the childhood survivors
102 of natural disasters for 20 years, while depression was not investigated¹⁴.

103 Our study provides a suitable setting for investigating the long-term effect of
104 disasters on depression. The Tangshan earthquake, which occurred in 1976, had a

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3 105 magnitude of 7.8 on the Richter scale²⁰. The earthquake caused 242,769 deaths and
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5 106 left 164,851 people severely injured, representing the most deadly and the strongest
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7 107 natural disaster in the twentieth century²⁰. Over the past 37 years, numerous studies
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9 108 have examined the effects of the Tangshan earthquake on physical health outcomes.
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11 109 These studies report increased risks of diabetes, cardiovascular disease, and elevated
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13 110 levels of uric acid among survivors of the Tangshan earthquake even more than 30
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15 111 years later²¹⁻²³. However, no study to date has examined the long-term effect of the
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17 112 Tangshan earthquake on the risk of depression.
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21 113 The aim of our study was to examine the long-term effect of disaster on depression
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23 114 37 years later. We hypothesized that the earthquake-exposed group would be more
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25 115 likely to exhibit depression. Furthermore, we expected that bereaved survivors would
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27 116 be more likely to experience depression than the non-bereaved. Considering that age
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29 117 and gender may confound the association between earthquake experience and
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31 118 depression, we also performed an analysis stratified by age and gender.
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38 120 **METHODS**

39 121 **Study participants**

40 122 The participants were selected from the Jidong Cohort, an ongoing community-based
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42 123 prospective study on Chinese adults²⁴. In brief, the Jidong community is located in the
43
44 124 Caofeidian district of Tangshan City, which is approximately 60 km from the
45
46 125 epicenter of the Tangshan earthquake. A clustering sample method was used to select
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48 126 participants. From July 2013 to August 2014, a total of 9078 residents in Jidong
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50 127 community were recruited to participate in the cohort. This cohort has prospectively
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52 128 collected data regarding demographic and behavioral characteristics, insomnia,
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54 129 cognition, depression, and biochemical indicators at annual follow-ups since 2013²⁵⁻
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3 130 ²⁷. These data were collected using a set of combined self-administered questionnaires
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5 131 (including the Center for Epidemiological Study and Depression Scale (CES-D)) with
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7 132 assistance of well-trained research nurses during face-to-face interviews. Biomedical
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9 133 variables were collected by physical examinations and laboratory assessments. The
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11 134 research field of this cohort has gradually expanded from the initial sub-health to
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13 135 depression, cardiovascular and cerebrovascular and other fields ²⁵⁻²⁸.

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17 136 In the current study, we excluded 4054 subjects from the 9078 participants
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19 137 according to the following standards: (1) born after July 28th, 1976 (n=4053), (2)
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21 138 incomplete information on relevant earthquake experience (n=1), and (3) missing
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23 139 values in the surveys for the CES-D measurement scale (n=0). Missing data for
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25 140 confounding variables (60 income variables) were imputed with their mean values
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27 141 among these participants. Finally, a total of 5024 individuals were included in this
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29 142 cross-sectional study. The response rate was 99.99% (5024/5025).

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33 143 This study was performed according to guidelines from the Helsinki Declaration
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35 144 and approved by the Ethics Committee of Jidong Oilfield Staff Hospital. All
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37 145 participants provided written informed consent.

38 39 40 146 41 42 147 **Assessment of the earthquake experience**

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44 148 The exposure variable of interest was earthquake experience. Earthquake experience
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46 149 and related bereavement were collected from a structured questionnaire. These factors
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48 150 were obtained using the question “Were you in the Tangshan earthquake area in
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50 151 1976?” and “Did you lose any relatives in the earthquake?”²³ According to the
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52 152 answers to these questions, subjects were classified into 3 groups: no earthquake
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54 153 experience, earthquake experience without bereavement, and earthquake experience
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56 154 with bereavement.

155 **Assessment of current depression**

156 Depressive symptoms were assessed using CES-D, which was initially developed by
157 the United States National Institute of Mental Health in 1977²⁹. The Chinese version
158 of the CES-D was translated by two psychiatrists on the basis of the international
159 standard version of the CES-D questionnaire in 1985 and was specifically designed to
160 screen for depression³⁰. The CES-D measures the frequency of common depressive
161 symptoms over the past week, which are surveyed through the questionnaire. Each
162 item in the depression assessment section of the questionnaire is scored from 0 (rarely
163 or none of the time, less than one day) to 3 (all of the time, 5–7 days). The four
164 positive statement items (item 4, I felt that I was just as good as other people; item 8, I
165 felt hopeful about the future; item 12, I was happy; item 16, I enjoyed life) are
166 reverse-coded to calculate the total score, which ranges from 0 to 60. The cut-off
167 value of ≥ 16 has been widely used to define clinically meaningful depressive
168 symptoms³¹⁻³³. All investigators attended a 3-day training course and were licensed
169 before conducting the CES-D interviews.

171 **Assessment of potential covariates**

172 The selected covariates included factors known to be predictive of depression and/or
173 potentially correlated with earthquake exposure, including age at the time of the
174 earthquake, gender, education, income, smoking, drinking, residence in Tangshan 1-2
175 years after the earthquake, hypertension, diabetes, and dyslipidemia.

176 Age at the time of the earthquake was defined as a continuous variable and a
177 categorical variable (“ ≤ 6 years”, “6-18 years”, or “ ≥ 18 years”). The average
178 monthly income of each family member was categorized as “ $< ¥3000$ ”, “ $¥3000-5000$ ”
179 or “ $> ¥5,000$ ”. Educational level was classified into three categories: “illiterate or

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3 180 primary school,” “middle school or high school,” and “university or above.” Smoking
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5 181 status was classified as “yes” (current smoker or quit <12 months ago) and “no”
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8 182 (nonsmoker or quit >12 months ago).” Drinking status was divided into “yes” (<1
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10 183 standard servings/day, <2 standard servings/day, 2-4 standard servings/day, >=5
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12 184 standard servings/day) and “no” (never drink). A standard serving was 15 g of
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14 185 ethanol. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were
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16 186 measured twice with the subject in a seated position using a mercury
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18 187 sphygmomanometer. If the difference between the two measurements exceeded 5 mm
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20 188 Hg, an additional reading was taken, and the average of the three readings was used.
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22 189 Hypertension was defined as having a history of hypertension, exhibiting an SBP
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24 190 ≥ 140 mm Hg or a DPB ≥ 90 mm Hg, or using antihypertensive medications. The
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26 191 definition of diabetes mellitus was a fasting glucose level ≥ 7.0 mmol/l (126 mg/dl),
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28 192 current treatment with insulin/oral hypoglycemic agents or a history of diabetes
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30 193 mellitus. Dyslipidemia was defined as having a history of hyperlipidemia, total blood
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32 194 cholesterol levels ≥ 220 mg/dl, triglyceride levels ≥ 150 mg/dl, or using anti-
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34 195 hyperlipidemic medications. All measures were current in this cross-sectional study.
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197 **Statistical analysis**

198 We first compared the characteristics of individuals according to their earthquake and
199 bereavement experiences (no earthquake experience, earthquake experience without
200 bereavement, and earthquake experience with bereavement) using the chi-square test
201 for categorical variables and one-way ANOVA or the Kruskal–Wallis test for
202 continuous variables.

203 We used logistic regression to examine the association between earthquake
204 experience and current depression, with "no earthquake experience" as the reference

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3 205 group. Four multivariate models were fitted as follows: Model 1 was the unadjusted
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5 206 model. Model 2 was adjusted for age at the time of the earthquake and gender. Model
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7 207 3 was further adjusted for smoking status, drinking status, education, income,
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9 208 residence in Tangshan 1-2 years after the earthquake. Model 4 was further adjusted
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11 209 for hypertension, diabetes, and dyslipidemia.
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15 210 We also used multiple logistic regression to examine the association stratified by
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17 211 gender and age at the time of the earthquake. To evaluate whether effect of the
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19 212 earthquake on depression would be modified by gender and age at the time of the
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21 213 earthquake, we tested the statistical significance of earthquake \times gender and
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23 214 earthquake \times age at the time of the earthquake in a multiple-adjustment logistic model
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25 215 by a post-estimation Wald test to obtain an omnibus P-value for the interactions
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27 216 between earthquake categories and depression.
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31 217 All statistical tests were 2-sided, and results with a P-value <0.05 were considered
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33 218 statistically significant. The analyses were performed in SAS version 9.4 (SAS
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35 219 Institute Inc., Cary, NC, USA).
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40 221 **Patient and public involvement**

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42 222 Patients and the public were not involved in development of the research question or
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44 223 outcome measures, study design, or recruitment to and conduct of this study. Results
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46 224 will be disseminated to study participants through annual information events.
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51 226 **RESULTS**

53 227 **Characteristics of the study participants**

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55 228 The characteristics of the participants according to earthquake and bereavement
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57 229 experiences are shown in Table 1. In total, 5024 participants were included in this
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3 230 study, with 50.2% male participants and current ages ranging from 37 to 82 years.
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5 231 Among all participants, 543 (10.8%) individuals experienced the earthquake without
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7 232 bereavement, and 98 (2.0%) participants lost relatives. The individuals who
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9 233 experienced the earthquake with or without bereavement were younger (12.1 ± 9.0 ,
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11 234 13.1 ± 9.1 vs. 14.8 ± 9.2 years, respectively) and were more likely to have lived in
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13 235 Tangshan 1-2 years after the earthquake (86.7%, 79.4% vs. 1%, respectively) than
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15 236 those who had not experienced the earthquake. No differences were found in gender,
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17 237 smoking status, drinking status, education, income, hypertension, diabetes or
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19 238 dyslipidemia. A higher incidence of depression was observed in the bereaved and
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21 239 non-bereaved groups (12.2% (39/543) and 7.2% (12/98), respectively) than in those
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23 240 without earthquake experience (4.9% (215/4383)).
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31 242 **Association of earthquake experience with depression**

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33 243 Odds ratios (ORs) with 95% confidence intervals (CIs) for the association between
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35 244 earthquake experience and depression are presented in Table 2. The risk of depression
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37 245 in the bereaved subgroup was 2.82-times (OR, 2.82; 95% CI, 1.24-6.39) higher than
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39 246 that in the group with no earthquake experience, after adjusting for gender, age at the
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41 247 time of the earthquake, smoking status, drinking status, education, income, residence
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43 248 in Tangshan 1-2 years after the earthquake, hypertension, diabetes, and dyslipidemia.
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45 249 However, no statistically significant association was found in the non-bereaved group.
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51 251 **Subgroup analysis by gender and age during the earthquake**

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53 252 In the models stratified by gender, the female subjects in both the bereaved (OR, 3.07;
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55 253 95% CI, 1.44-6.56) and non-bereaved (OR, 3.51; 95% CI, 1.21-10.16) subgroups had
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57 254 an increased risk of depression. In the models stratified by age at the time of the
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3 255 earthquake, we found a statistically significant association in individuals over 18
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5 256 years with bereavement (OR, 13.16; 95% CI, 3.08-56.3) or without bereavement (OR,
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7 257 3.39; 95% CI, 1.31-8.87). We also found a statistically significant interaction between
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9 258 gender and depression (P for interaction= 0.02), but not significant between age at the
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11 259 time of the earthquake and depression (P for interaction= 0.51) (Figure 1).
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16 17 261 **DISCUSSION**

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19 262 In the community-based study, we observed that earthquake survivors had a higher
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21 263 risk of depression than those who did not experience an earthquake even 37 years
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23 264 later. In addition, long-term effects of an earthquake on depression were found among
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25 265 survivors with bereavement, women and individuals over 18 years. This is the first
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27 266 study to investigate the association between earthquake experience and depression as
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29 267 long as 37 years after an earthquake.
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33 268 Consistent with our findings, a longitudinal study on the Alexander Kiedand oil
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35 269 platform collapse shows that survivors have a higher risk of depression than non-
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37 270 exposed individuals 27 years after the disaster¹⁵. Similar results are observed in
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39 271 another longitudinal study with 10 years of follow-up, which indicates that survivors
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41 272 of the Piper Alpha oil platform disaster show continued problems of mental health
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43 273 compared with non-exposed individuals¹⁶. In contrast, some previous studies report
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45 274 no significant differences between exposed population and non-exposed population in
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47 275 mental health^{13 14}. The inconsistent results may be explained by 3 reasons. First,
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49 276 subclinical psychotic experiences (SPE) and depression reflect different aspects of
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51 277 psychological problems. SPE is defined as symptoms or experiences of or experiences
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53 278 resembling hallucinations, delusions or both³⁴, whereas depressive disorder is
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55 279 characterized by sadness or irritability³⁵. Differences in symptoms may explain why
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3 280 our findings differ from the results of the 20-year follow-up study of Australian bush
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5 281 fires. Second, psychological problems may depend on the severity of a trauma. For
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7 282 example, Galletly C et al reported that the risk of psychological disorder is associated
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9 283 with multiple traumas rather than a single major trauma¹⁴. Third, the trauma
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11 284 experiences of the participants in these studies are different. In the study on Buffalo
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13 285 Creek survivors, few survivors suffer from bereavement¹³, which is different from the
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15 286 survivors in our study. Different characteristics of trauma experiences between the
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17 287 two studies may account for the discrepancy.

21 288 The long-term effect of disaster on depression seems to depend on traumatic
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23 289 experience. In our study, a statistically significant association between earthquake
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25 290 experience and depression was observed in bereaved survivors but not in non-
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27 291 bereaved survivors 37 years after the earthquake. The finding was consistent with a
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29 292 longitudinal study carried out in Italian, which shows that exposure to loss and
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31 293 damage during the earthquake is of higher risk of negative psychological
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33 294 consequences than these merely live in the earthquake zone¹⁰. Similarly, a
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35 295 longitudinal study on MS Estonia Disaster indicates that psychological disorders can
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37 296 persist in bereaved survivors but not in non-bereaved survivors 14 years after the
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39 297 disaster¹². Traumatic bereavement may be associated with more severe long-term
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41 298 posttraumatic stress reactions after disasters³⁶, which is considered to be involved in
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43 299 the onset of depression⁴.

49 300 Several plausible explanations may link earthquake exposure to the prevalence of
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51 301 depressive symptoms. Earthquakes can cause tremendous, immediate damage to the
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53 302 environment and even lead to adverse life events such as the death of a family
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55 303 member and related events, thus exerting negative effects on individuals' emotions
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57 304 and resulting in long-term posttraumatic stress reactions after the disaster^{4 12}. Long-
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3 305 term posttraumatic stress reactions may affect neurobiological adjustments, which
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5 306 have been linked to several brain areas (the frontolimbic and striatal areas)^{36 37}. These
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7 307 areas and the functional connectivities located within the fronto-striato-thalamic and
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9 308 default-mode networks have been found to be correlated with progression of
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11 309 depressive symptom and may play important roles in adaptation to trauma^{4 38}.

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14 310 Gender, age at the time of the earthquake, education, income, smoking, drinking,
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16 311 living in the affected area after a disaster, hypertension, diabetes and dyslipidemia
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18 312 were controlled in the multiple variable analysis. To avoid over-adjustment, four
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20 313 models were used to adjust confounding variables step by step. The resulting ORs
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22 314 reflected minor changes in the 4 models, suggesting that earthquake experience may
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24 315 be an independent risk factor for the occurrence of depression.

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27 316 Evidence shows that trauma experience in childhood and adolescence may have a
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29 317 determining effect on brain structural development, sympathetic nervous system
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31 318 responsivity, and the hypothalamic pituitary adrenal axis, especially in younger
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33 319 children (preschool) and school-age children (late childhood and early adolescence),
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35 320 resulting in a large stress response and some psychological problems¹⁸. Therefore, we
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37 321 classified age into 0-6, 6-18 and older than 18 years to investigate the long-term
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39 322 impact of disaster on mental health at different age stages. However, statistically
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41 323 significant associations were found only in individuals over 18 years. One possible
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43 324 explanation is that perception of disaster-related stressors in the ≤ 6 and 6-18 years
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45 325 age groups is different from that in the >18 years age group. Disaster trauma as a
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47 326 stressor is not sufficient to promote mental illness among individuals at the ages of 0-
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49 327 6 and 6-18 years. A preschool child has less specific cognitive awareness of the nature
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51 328 and meaning of disaster trauma³⁹. Although a school-age child has a more mature
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53 329 cognitive understanding of the nature of a trauma situation and may respond with
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3 330 symptoms related to depression, parental care and family play important roles in
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5 331 determining the risk of psychological disorder among school-age children⁴⁰. We also
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7 332 found a long-term effect of earthquake experience on depression in women. Similar
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9 333 results have been found in several previous studies of disaster, indicating that women
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11 334 may be at a higher risk of depression than men^{13 19}.

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14 335 Our study had a few limitations. First, substantial time has passed since the
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16 336 earthquake occurred, and we were unable to control for every event or factor. For
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18 337 example, we did not consider other traumatic events, such as traffic accidents, adverse
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20 338 childhood experiences, other bereavement or current psychological stressors, which
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22 339 could have confounded the observed associations. Additionally, the sample was not
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24 340 representative of all survivors of the Tangshan earthquake. We did not include
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26 341 survivors who had died in the past 37 years. Premature death may be related to
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28 342 depression and disease. Meanwhile, in our sample, nearly 20% of the survivors did
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30 343 not live in the earthquake zone 1-2 years after the earthquake. These people left the
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32 344 painful environment and may have attended school or worked in another place for
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34 345 several years, which may have largely relieved psychological stress and alleviated the
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36 346 symptoms of depression. Therefore, the potential impacts of the earthquake on
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38 347 depression may have been underestimated. Third, whether the subjects were taking
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40 348 antidepressants was unknown. Fourth, this is a cross-sectional study, which precludes
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42 349 causal inferences. However, since the earthquake is immutable, the earthquake is
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44 350 likely to be the cause of depression. Finally, depression was assessed only once
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46 351 during the study; therefore, we could not exclude the possibility of reverse causality.

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48 352 The results of our study are very relevant to future research on depression among
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50 353 disaster survivors. For instance, survivors of earthquakes in Japan, Haiti, and China
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52 354 were all affected by high rates of depression in the short term⁴¹⁻⁴⁴. Although the time
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3 355 and severity of a disaster, the ethnicity of the affected population, and the growing
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5 356 environment are different, the stressors caused by disasters are similar. Intervention is
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8 357 highly effective in facilitating recovery from disaster trauma^{45 46}. Clinicians and
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10 358 policymakers in public health should direct more attention toward high-risk survivors
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12 359 of disasters, which may reduce the incidence of mental health problems, including
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14 360 depression, in disaster zones⁴⁷, even if the disaster has passed for a long time.
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19 362 **CONCLUSIONS**

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21 363 Earthquake experience had long-lasting effects on depression among bereaved
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23 364 survivors, women and individuals over 18 years 37 years later. Our study provides
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25 365 evidence supporting the hypothesis that the effect of an earthquake on depression
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28 366 persists for 37 years.
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15
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17
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19
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21
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34 **Competing interests** None declared.
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37 **Ethics approval** The research was approved by the Ethics Committee of Jidong
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39 Oilfield Staff Hospital.
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42 **Data sharing statement** The data used or analyzed during the current study are
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44 available from the corresponding author upon reasonable request.
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Table 1 Population characteristics according to earthquake experience

Characteristics	Overall	No experience (n=4383)	Experience without bereavement (n=543)	Experience with loss of family (n=98)	<i>P-value</i>
Men, n (%)	2524 (50.2)	2210 (50.4)	276 (50.8)	38 (38.8)	0.07
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	<0.0001
=<6	1063 (21.2)	880 (20.08)	146 (26.89)	37 (37.76)	<.0001
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)	0.18
Drinking, n (%)	1578 (31.4)	1364 (31.1)	186 (34.3)	28 (28.6)	0.28
Education, n (%)					0.69
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 (%)					0.13
≤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)	<0.0001
Hypertension, n (%)	2158 (43.0)	1872 (42.7)	237 (43.7)	45 (45.9)	0.46
Diabetes, n (%)	550 (11.0)	497 (11.3)	43 (7.9)	10 (10.2)	0.05
Dyslipidemia, n (%)	3102 (61.7)	2696 (61.5)	343 (63.2)	63 (64.3)	0.66
Depression, n (%)	266 (5.3)	215 (4.9)	39 (7.2)	12 (12.2)	0.0007

Table 2. Odds ratios for the association between earthquake experience and depression

	no earthquake experience	experience without bereavement	experience with bereavement
	(n=4383, 87.2%)	(n=543, 10.8%)	(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 1-2 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 1-2 years after the earthquake, hypertension, diabetes, and dyslipidemia.

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3 367 **Figure 1** Odds Ratio of earthquake experience for depression stratified by gender and
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5 368 age at the time of the earthquake.

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7 369 Adjusted for gender, age at the time of the earthquake, smoking status, drinking
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9 370 status, education, income, residence in Tangshan 1-2 years after the earthquake,
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11 371 hypertension, diabetes, and dyslipidemia.

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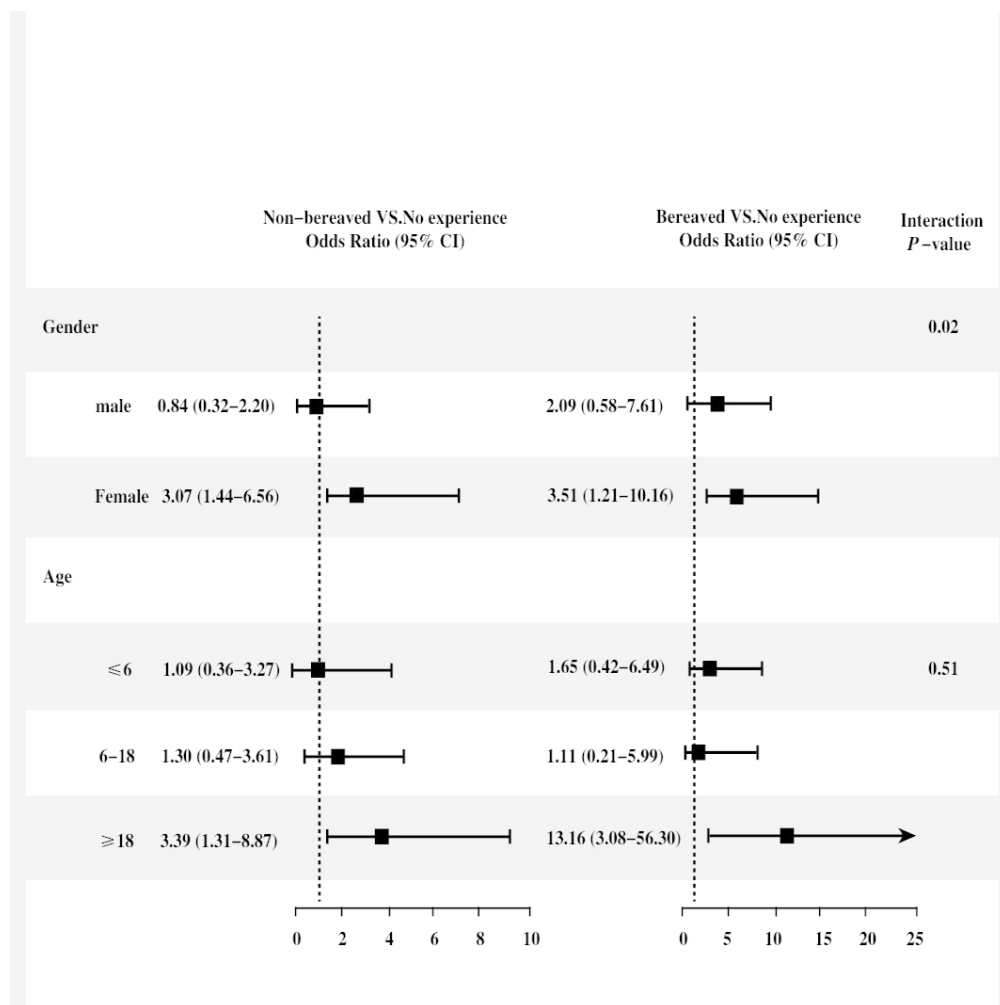


Figure 1 Odds Ratio of earthquake experience for depression stratified by gender and age at the time of the earthquake.

Adjusted for gender, age at the time of the earthquake, smoking status, drinking status, education, income, residence in Tangshan 1-2 years after the earthquake, hypertension, diabetes, and dyslipidemia.

90x90mm (300 x 300 DPI)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No.	Recommendation	Page No.	Relevant text from manuscript
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1	Line 1-2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	3-4	Line 44-69
Introduction				
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6-7	Line 81-112
Objectives	3	State specific objectives, including any prespecified hypotheses	7	Line 113-118
Methods				
Study design	4	Present key elements of study design early in the paper	8	Line 141-142
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7-8	Line 122-135
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	8	Line 136-142
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case		NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8-10	Line 148-195
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	8-9	Line 148-169
Bias	9	Describe any efforts to address potential sources of bias	11	Line 203-209
Study size	10	Explain how the study size was arrived at	8	Line 136-142

Continued on next page

Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	10	Line 198-202		
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	10-11	Line 198-219		
		(b) Describe any methods used to examine subgroups and interactions	11	Line 210-216		
		(c) Explain how missing data were addressed	8	Line 137-141		
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed <i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	7	Line 125-126		
		(e) Describe any sensitivity analyses		NA		
Results						
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	11-12	Line 229-232		
		(b) Give reasons for non-participation at each stage	8	Line 136-142		
		(c) Consider use of a flow diagram		NA		
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11-12	Line 228-240, Table 1		
		(b) Indicate number of participants with missing data for each variable of interest	8	Line 137-141		
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)		NA		
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time <i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure <i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	12	Line 238-240		
		Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12-13	Line 243-249, Table 2
				(b) Report category boundaries when continuous variables were categorized	9	Line 176-179, Table 1
(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period				NA		

Continued on next page

Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12-13	Line 252-259
Discussion				
Key results	18	Summarise key results with reference to study objectives	13	Line 262-267
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16	Line 335-351
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-17	Line 268-360
Generalisability	21	Discuss the generalisability (external validity) of the study results	16	Line 339-347
Other information				
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	18	Line 377-380

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

The Association between Earthquake Experience and Depression 37 Years after the Tangshan Earthquake: A Cross-sectional Study

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Keywords:	Depression & mood disorders < PSYCHIATRY, Earthquake, Association, EPIDEMIOLOGY

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3 1 **The Association between Earthquake Experience and Depression 37 Years after**
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5 2 **the Tangshan Earthquake: A Cross-sectional Study**

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3 36 **ABSTRACT**
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5 37 **Objective** To investigate the association between the Tangshan earthquake and the
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8 38 risk of depression after 37 years.
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10 39 **Design and setting** A cross-sectional study conducted in Tangshan from 2013 to
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12 40 2014.
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14 41 **Participants** The sample included 5024 participants born before July 28, 1976, the
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16
17 42 date of the Tangshan earthquake, with available data on their earthquake experiences
18
19 43 and depression 37 years after the earthquake.
20

21 44 **Outcomes and variables** The outcome was depression measured using the Center for
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23
24 45 Epidemiological Study and Depression Scale (CES-D). The independent variable was
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26 46 earthquake experience, which was classified into 3 groups: no earthquake experience,
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28 47 earthquake experience without bereavement, and earthquake experience with
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31 48 bereavement. Multivariable logistic regression analysis was used to evaluate the
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33 49 association between earthquake experience and depression after adjusting for gender,
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35 50 age at the time of the earthquake, smoking status, drinking status, education, income,
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38 51 residence in Tangshan 1-2 years after the earthquake, hypertension, diabetes, and
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40 52 dyslipidaemia.
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42 53 **Results** Of the 5024 participants, 641 had experienced the Tangshan earthquake, and
43
44 54 98 had experienced bereavement due to the earthquake. As of 37 years after the
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46
47 55 earthquake, participants who had experienced the earthquake (with or without
48
49 56 bereavement) had a higher prevalence of depression than those without earthquake
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51 57 experience (12.2%, 7.2% vs. 4.9%, respectively). Survivors who had lost relatives
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53 58 during the earthquake were nearly 3 times (odds ratio 2.82, 95% confidence interval
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55 59 1.24-6.39) as likely to have depression as those who had not experienced the
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58 60 earthquake. A statistically significant association between the earthquake and
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3 61 depression was found in women but not men and in individuals who were over 18
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5 62 years of age at the time of the earthquake.
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8 63 **Conclusions** Thirty-seven years after the Tangshan earthquake, earthquake
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10 64 experience was associated with depression among bereaved survivors, women and
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12 65 individuals over 18 years old at the time.
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For peer review only

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3 68 **Strengths and limitations of this study**
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5 69 ● The study investigated the long-term risk of depression 37 years after a major
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8 70 earthquake.

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10 71 ● Participants were stratified by gender and age at the time of the earthquake.

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12 72 ● We were unable to control for every event or factor, such as adverse childhood
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14 73 experiences, other bereavement or current psychological stressors.

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17 74 ● Only participants who were still alive 37 years after the earthquake were able to
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19 75 participate in the study.
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76 INTRODUCTION

77 Depression is predicted to be a major reason for disability around the world by 2030,
78 according to the World Health Organization¹. In addition, the chronic and debilitating
79 nature of depression complicates the prognosis of chronic diseases, aggravates various
80 diseases and may lead to suicide²⁻⁴. Evidence shows that depression is related to
81 demographic characteristics, living habits, education, income, and health status⁵⁻⁷.

82 Participants exposed to disasters at an early life stage are at an increased risk of
83 depression in the short term (1-4 years), independent of age, gender, income,
84 education and other confounders⁸⁻¹⁰. Additionally, studies report that some survivors
85 have psychological problems in the immediate aftermath of disaster trauma; most of
86 these reactions abate over time, and only a minority of survivors develop a
87 long-standing disorder^{11 12}. Therefore, long-term evidence is essential to evaluate the
88 effects of disaster on depression.

89 Findings regarding the long-term impact of disasters on mental health have been
90 mixed. Several studies have reported no significant differences^{13 14}, but others have
91 revealed more psychological problems in exposed individuals than in non-exposed
92 individuals for more than a decade after disasters^{10 15 16}. Moreover, evidence shows
93 that such effects are increased if survivors suffer from bereavement^{10 12}. Additionally,
94 the association between earthquakes and depression may vary according to age or
95 gender. Studies indicate that overall levels of psychological symptoms may vary
96 among children, adolescents, and adults due to differences in physiology and
97 cognition^{17 18}. In response to disaster, women appear develop more intense and
98 longer-lasting psychological symptoms than men^{13 19}. However, very few of these
99 studies investigated the long-term effect of earthquakes on depression risk in the
100 Chinese population.

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3 101 Our study provides a suitable setting for investigating the long-term impact of
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5 102 earthquakes on depression in the Chinese population. The Tangshan earthquake,
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7 103 which occurred in 1976, had a magnitude of 7.8 on the Richter scale²⁰. The
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9 104 earthquake caused 242,769 deaths and left 164,851 people severely injured,
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11 105 representing the strongest and deadliest natural disaster in the twentieth
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13 106 century²⁰. Since the earthquake, numerous studies have examined the effects of the
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15 107 event on physical health outcomes. These studies report increased risks of diabetes,
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17 108 cardiovascular disease, and elevated levels of uric acid among survivors of the
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19 109 Tangshan earthquake even at timepoints more than 30 years later²¹⁻²³. However, no
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21 110 study to date has examined the long-term effect of the Tangshan earthquake on the
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23 111 risk of depression.

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26 112 The aim of our study was to examine the long-term effect of disaster on depression 37
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28 113 years later. We hypothesized that the earthquake-exposed group would be more likely
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30 114 than the non-exposed group to exhibit depression. Furthermore, we expected that
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32 115 bereaved survivors would be more likely to experience depression than non-bereaved
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34 116 survivors. Considering that age and gender may confound the association between
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36 117 earthquake experience and depression, we also performed an analysis stratified by age
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38 118 and gender.

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46 120 **METHODS**

47 121 **Study participants**

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49 122 The participants were selected from the Jidong Cohort, an ongoing community-based
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51 123 prospective study in Chinese adults²⁴. The Jidong community is located in the
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53 124 Caofeidian district of Tangshan City, which is approximately 60 km from the
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55 125 epicentre of the Tangshan earthquake. Cluster sampling was used to select
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3 126 participants. From July 2013 to August 2014, a total of 9078 residents in the Jidong
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5 127 community were recruited to participate in the cohort. Data regarding demographic
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7 128 and behavioural characteristics, insomnia, cognition, depression, and biochemical
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9 129 indicators have been collected from this cohort at annual follow-ups since
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11 130 2013²⁵⁻²⁷. These data were collected using a set of self-administered questionnaires
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13 131 (including the Center for Epidemiological Study and Depression Scale (CES-D)) with
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15 132 the assistance of well-trained research nurses during face-to-face interviews.
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17 133 Biomedical variables were collected by physical examinations and laboratory
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19 134 assessments. Research on this cohort originally examined sub-health and later
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21 135 expanded to examine depression, cardiovascular health, cerebrovascular health and
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23 136 other areas²⁵⁻²⁸.

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27
28 137 In the current study, we excluded 4054 of the 9078 candidate participants according
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30 138 to the following standards: (1) birth date after July 28th, 1976 (n=4053); (2)
31
32 139 incomplete information on relevant earthquake experience (n=1); and (3) missing
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34 140 values in the surveys for the CES-D measurement scale (n=0). Missing data for
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36 141 confounding variables (60 income variables) were imputed with their mean values
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38 142 among these participants. Ultimately, a total of 5024 individuals were included in this
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40 143 cross-sectional study. The participants in the Jidong Cohort are subjected to a physical
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42 144 examination annually, which is paid for by the community. Therefore, the response
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44 145 rate was almost 100%(5024/5025).

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48 146 This study was performed according to guidelines from the Declaration of Helsinki
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50 147 and approved by the Ethics Committee of Jidong Oilfield Staff Hospital. All
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52 148 participants provided written informed consent.
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57 58 150 **Assessment of earthquake experience**

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3 151 The exposure variable of interest was experience with the earthquake. Earthquake
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5 152 experience and related bereavement were collected through a structured questionnaire.
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8 153 These factors were obtained using the following questions: “Were you in the
9
10 154 Tangshan earthquake area in 1976?” and “Did you lose any relatives in the
11
12 155 earthquake?”²³ According to the answers to these questions, subjects were classified
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14 156 into 3 groups: no earthquake experience, earthquake experience without bereavement,
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17 157 and earthquake experience with bereavement.
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23 159 **Assessment of current depression**

24 160 Depressive symptoms were assessed using the CES-D, which was initially developed
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26 161 by the United States National Institute of Mental Health in 1977²⁹. The Chinese
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28 162 version of the CES-D was translated from the international standard version of the
29
30 163 CES-D questionnaire in 1985 by two psychiatrists and was specifically designed to
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32 164 screen for depression³⁰. The CES-D questionnaire surveys the frequency of common
33
34 165 depressive symptoms over the past week. Each item in the depression assessment
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36 166 section of the questionnaire is scored from 0 (rarely or none of the time, less than one
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38 167 day) to 3 (all of the time, 5–7 days). The four positive statement items (item 4, I felt
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40 168 that I was just as good as other people; item 8, I felt hopeful about the future; item 12,
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42 169 I was happy; item 16, I enjoyed life) are reverse coded to calculate the total score,
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45 170 which ranges from 0 to 60. A cut-off value of ≥ 16 has been widely used to define
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47 171 clinically meaningful depressive symptoms³¹⁻³³. All investigators attended a 3-day
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49 172 training course and were licensed before conducting the CES-D interviews.
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56 174 **Assessment of potential covariates**

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58 175 The selected covariates included factors known to be predictive of depression and/or
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3 176 potentially correlated with earthquake exposure, including age at the time of the
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5 177 earthquake, gender, education, income, smoking status, drinking status, residence in
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7 178 Tangshan 1-2 years after the earthquake, hypertension, diabetes, and dyslipidaemia.
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10 179 Age at the time of the earthquake was defined as a continuous variable and then a
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12 180 categorical variable (“≤6 years”, “6-18 years”, or “≥18 years”). The average monthly
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14 181 income of each family member was categorized as “<¥3000”, “¥3000–5000” or
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16 182 “>¥5,000”. Educational level was classified into three categories: “illiteracy or
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18 183 primary school,” “middle school or high school,” and “university or above.”
19
20 184 Residence in Tangshan 1-2 years after the earthquake was classified as “yes” and “no”.
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22 185 Smoking status was classified as “yes” (current smoker or quit<12 months ago) and
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24 186 “no” (nonsmoker or quit>12 months ago).” Drinking status was divided into “yes”
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26 187 (current drinking <1 standard servings/day, <2 standard servings/day, 2-4 standard
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28 188 servings/day, ≥5 standard servings/day) and “no” (never drank, drank in the past).A
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30 189 standard serving was defined as 15 g of ethanol. Systolic blood pressure (SBP) and
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32 190 diastolic blood pressure (DBP) were measured twice using a mercury
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34 191 sphygmomanometer with the subject in a seated position. If the difference between
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36 192 the two measurements exceeded 5 mm Hg, an additional reading was taken, and the
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38 193 average of the three readings was used. Hypertension was defined as having a history
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40 194 of hypertension, exhibiting an SBP ≥140 mm Hg or a DBP≥90 mm Hg, or using
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42 195 antihypertensive medications. The definition of diabetes mellitus was a fasting
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44 196 glucose level ≥7.0 mmol/l (126 mg/dl), current treatment with insulin/oral
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46 197 hypoglycaemic agents or a history of diabetes mellitus. Dyslipidaemia was defined as
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48 198 a history of hyperlipidaemia, a total blood cholesterol level ≥220 mg/dl, a triglyceride
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50 199 level≥150 mg/dl, or use of anti-hyperlipidaemic medications. All measures in this
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52 200 cross-sectional study reflected the current values as of data collection.
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3 201 **Statistical analysis**
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5 202 We first compared the characteristics of individuals according to their earthquake and
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7 203 bereavement experiences (no earthquake experience, earthquake experience without
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9 204 bereavement, and earthquake experience with bereavement) using the chi-squared test
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11 205 for categorical variables and one-way ANOVA or the Kruskal–Wallis test for
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13 206 continuous variables.
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17 207 We used logistic regression to examine the association between earthquake
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19 208 experience and current depression, with "no earthquake experience" as the reference
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21 209 group. Four multivariate models were fitted as follows: Model 1 was the unadjusted
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23 210 model. Model 2 was adjusted for age at the time of the earthquake and gender. Model
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25 211 3 was further adjusted for smoking status, drinking status, education, income, and
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27 212 residence in Tangshan 1-2 years after the earthquake. Model 4 was further adjusted
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29 213 for hypertension, diabetes, and dyslipidaemia.
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33 214 We also used multiple logistic regression to examine the association stratified by
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35 215 gender and age at the time of the earthquake. To evaluate whether the effect of the
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37 216 earthquake on depression would be modified by gender and/or age at the time of the
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39 217 earthquake, we tested the statistical significance of earthquake \times gender and
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41 218 earthquake \times age at the time of the earthquake as interaction effects in a
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43 219 multiple-adjustment logistic model by applying a post-estimation Wald test to obtain
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45 220 an omnibus P-value for the interactions between earthquake categories and
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47 221 depression.
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51 222 All statistical tests were 2-sided, and results with a P-value <0.05 were considered
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53 223 statistically significant. The analyses were performed in SAS version 9.4 (SAS
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55 224 Institute Inc., Cary, NC, USA).
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226 **Patient and public involvement**

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

230

231 **RESULTS**

232 **Characteristics of the study participants**

233 The characteristics of the participants according to earthquake and bereavement
234 experiences are shown in Table 1. In total, 5024 participants were included in this
235 study; the participants were 50.2% male and ranged in age from 37 to 82 years at the
236 time of data collection. Among all participants, 543 (10.8%) individuals experienced
237 the earthquake without bereavement, and 98 (2.0%) participants lost relatives. The
238 individuals who experienced the earthquake with or without bereavement were
239 younger and were more likely to have lived in Tangshan 1-2 years after the
240 earthquake than those who had not experienced the earthquake(12.1±9.0,
241 13.1±9.1,and 14.8±9.2 years, respectively, for age;86.7%, 79.4%, and 1%,
242 respectively, for residence). No differences were found in gender, smoking status,
243 drinking status, education, income, hypertension, diabetes or dyslipidaemia. A higher
244 incidence of depression was observed in the bereaved and non-bereaved earthquake
245 survivors(12.2% (39/543) and 7.2% (12/98), respectively) than in those without
246 earthquake experience (4.9% (215/4383)).

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248 **Association between earthquake experience and depression**

249 Odds ratios (ORs) and 95% confidence intervals (CIs) for the association between
250 earthquake experience and depression are presented in Table 2. The risk of depression

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3 251 in the bereaved subgroup was 2.82 times (OR, 2.82; 95% CI, 1.24-6.39) higher than
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5 252 that in the group with no earthquake experience after adjusting for gender, age at the
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7 253 time of the earthquake, smoking status, drinking status, education, income, residence
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9 254 in Tangshan 1-2 years after the earthquake, hypertension, diabetes, and dyslipidaemia.
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12 255 However, no statistically significant association was found in the non-bereaved group.
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16 17 257 **Subgroup analysis by gender and age as of the earthquake**

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19 258 In the models stratified by gender, the female subjects in both the bereaved (OR, 3.51;
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21 259 95% CI, 1.21-10.16) and non-bereaved (OR, 3.07; 95% CI, 1.44-6.56) subgroups had
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23 260 an increased risk of depression. In contrast, no significant association was found
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25 261 between earthquake experience and the risk of depression among male subjects in
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27 262 either the bereaved (OR, 2.09; 95% CI, 0.58-7.61) or the non-bereaved (OR, 0.84; 95%
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29 263 CI, 0.32-2.20) subgroup. In the models stratified by age at the time of the earthquake,
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31 264 we found a statistically significant association in individuals over 18 years old
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33 265 whether they had lost relatives in the earthquake (OR, 13.16; 95% CI, 3.08-56.3) or
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35 266 not (OR, 3.39; 95% CI, 1.31-8.87). No statistically significant association was found
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37 267 in survivors under 6 years old whether they had been bereaved (OR, 1.65; 95% CI,
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39 268 0.42-6.49) or not (OR, 1.09; 95% CI, 0.36-3.27), and there was also no significant
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41 269 association in survivors aged between 6 and 18 years whether they had lost relatives
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43 270 (OR, 1.11; 95% CI, 0.21-5.99) or not (OR, 1.30; 95% CI, 0.47-3.61). In addition, we
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45 271 found a statistically significant interaction between gender and depression (P for
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47 272 interaction= 0.02) but no significant interaction between age at the time of the
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49 273 earthquake and depression (P for interaction= 0.51) (Figure 1).
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57 58 275 **DISCUSSION**

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3 276 In this community-based study, we observed that, even after 37 years, earthquake
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5 277 survivors had a higher risk of depression than those who had not experienced the
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8 278 earthquake. In addition, long-term effects of the earthquake on depression were found
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10 279 among bereaved survivors, women and individuals over 18 years old. This study is
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12 280 the first to investigate the association between earthquake experience and depression
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15 281 37 years after an earthquake.

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17 282 Evidence shows that traumatic experiences in childhood and adolescence may have a
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19 283 determining effect on brain structural development, sympathetic nervous system
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21 284 responsivity, and the hypothalamic–pituitary–adrenal axis, especially in younger
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24 285 children (preschool) and school-age children (late childhood and early adolescence),
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26 286 resulting in a large stress response and some psychological problems¹⁸. Therefore, we
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28 287 classified the participants into age categories of 0-6, 6-18 and older than 18 years to
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30 288 investigate the long-term impact of disaster on mental health during different stages
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33 289 of life. However, statistically significant associations were found only in individuals
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35 290 over 18 years of age. One explanation is that different ages have different needs for
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37 291 social networks. Social networking is associated with the onset of depression³⁴.
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39 292 Children's and adolescents' social needs are met by parental care and family³⁵. Adults,
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41 293 in contrast, need support from social interaction in the neighbourhood, the
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43 294 communities, and the work place in addition to family support³⁶. The advent of the
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45 295 earthquake destroyed the previously stable social networks and economic foundation
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47 296 of the community. Social-network destruction may lead to some mental health
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49 297 disorders. Additionally, survivors under 18 years old recover from disaster more
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51 298 easily than older survivors do. Insensitivity to the nature and meaning of disaster
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54 299 trauma³⁷ and access to mental health intervention in the early postdisaster stages³⁸ may
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3 300 contribute to recovery from psychological problems among child and adolescent
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5 301 survivors.
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7 302 With regard to gender, we found a significant association between earthquake
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9 303 experience and depression in females but not in males. Similar results have been
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11 304 found in several previous studies of disaster, indicating that women may be at a
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13 305 higher risk of depression than men^{13 19}. One explanation of this gender difference is
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15 306 that men tend to externalize stress, while women tend to internalize it³⁹. Thus, of the
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17 307 two genders, women have higher rates of anxiety and depression (internalizing
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19 308 disorders), and men have higher rates of substance abuse (externalizing disorders)⁴⁰.
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21 309 Additionally, difference may be related to the culturally taught goals and roles of men
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23 310 and women in society and the family. Men are required to have innate masculinity
24
25 311 and strength, while women are required to show empathy and tender-mindedness^{41 42}.
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27 312 Consequently, in the face of disasters, men are more stress-resistant than women and
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29 313 recover more quickly. Women are more likely than men to be sentimental than men⁴³
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31 314 ⁴⁴. Once women fall into deep emotional pain, it is difficult for them to extricate
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33 315 themselves⁴⁵. We also found that, in female, the risk of depression was 3 times higher
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35 316 in the group with earthquake experience group than in the group without. One
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37 317 interpretation of this finding is that there are some components of earthquake-related
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39 318 aftermath that weaken women's psychological defence mechanisms. Evidence show
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41 319 that women are more likely than men to carry out rumination⁴⁶, which is characterized
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43 320 by continuous and repetitive thinking about painful memories⁴⁷. When fear memories
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45 321 of earthquake-related morbidity, mortality, and destruction constantly resurface,
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47 322 women who have experienced earthquake face long-lasting emotional pain that can
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49 323 lead to depression.
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3 324 Consistent with our findings, a longitudinal study on the Alexander Kielland oil
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5 325 platform collapse shows that survivors have a higher risk of depression than
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7 326 non-exposed individuals 27 years after the disaster¹⁵. Similar results are observed in
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9 327 another longitudinal study with 10 years of follow-up, which indicates that survivors
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11 328 of the Piper Alpha oil platform disaster show a long-lasting increase in mental health
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13 329 problems compared with non-exposed individuals¹⁶. In contrast, two studies indicate
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15 330 that disaster has little long-term effect on depression^{13 14}. The inconsistency of the
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17 331 results may be explained by the severity of the disaster. The Tangshan earthquake
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19 332 caused more damage than the Buffalo Creek dam collapse or the Australian bushfire
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21 333 disaster. The earthquake reduced Tangshan to ruins in a few minutes, with
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23 334 approximately 85% of the buildings collapsed and at least 400,000 casualties^{20 48}. The
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25 335 earthquake afflicted the survivors with not only the loss of their homes but also, more
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27 336 importantly, the tension and fear brought by the disaster itself, the loss of loved ones,
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29 337 the complete destruction of social networks and a sense of despair^{49 50}. During the
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31 338 long-term urban reconstruction process, all these effects of the disaster might lead to
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33 339 long-term adverse psychological effects on the survivors. In addition, the Tangshan
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35 340 earthquake broke out at the end of the decade of the Cultural Revolution. The
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37 341 consequences of the Cultural Revolution, which include a fragile economic
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39 342 foundation, low economic compensation, lack of societal acknowledgement, and
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41 343 destruction of the health care service network, may have delayed recovery.
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43 344 The long-term effect of disaster on depression seems to depend on traumatic
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45 345 experience. In our study, a statistically significant association between earthquake
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47 346 experience and depression was observed in bereaved survivors but not in
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49 347 non-bereaved survivors 37 years after the earthquake. This finding was consistent
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51 348 with a longitudinal study carried out in Italy showing that exposure to loss and
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3 349 damage during an earthquake confers an additional risk of negative psychological
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5 350 consequences above and beyond living in the earthquake zone¹⁰. Similarly, a
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7 351 longitudinal study 14 years after MS Estonia Disaster indicated that non-bereaved
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9 352 survivors recovered from their posttraumatic stress reactions, while little change was
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11 353 found over that period in the reaction of the bereaved¹². Traumatic bereavement may
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13 354 be associated with increased severity of long-term posttraumatic stress reactions after
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15 355 disasters⁵¹, which is considered to be involved in the onset of depression⁴.
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17 356 Several plausible explanations may link earthquake exposure to the prevalence of
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19 357 depressive symptoms. Earthquakes can cause tremendous, immediate damage to the
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21 358 environment and even lead to adverse life events such as the death of a family
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23 359 member and related events, thus exerting negative effects on individuals' emotions
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25 360 and resulting in posttraumatic stress disorder (PTSD) after the disaster^{4 12}. PTSD, as a
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27 361 frequent comorbidity of depression^{52 53}, may persist for decades following disaster⁵⁴⁻⁵⁶.
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29 362 These findings suggest that traumatic bereavement might be a common mediating
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31 363 mechanism of both depression and PTSD. The pain of loss in survivors may have
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33 364 neurobiological effects on several brain areas (the frontolimbic and striatal areas)^{51 57}.
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35 365 These areas and the functional connectivity within the fronto-striato-thalamic and
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37 366 default-mode networks have been found to be correlated with the progression of
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39 367 mental health problems and may play important roles in adaptation to trauma^{4 58}. The
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41 368 trauma caused by disasters has a variety of mechanisms. Whether PTSD symptoms
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43 369 further transform into depression or other mental illnesses in the long term will
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45 370 require further exploration.
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47 371 Gender, age at the time of the earthquake, education, income, smoking, drinking,
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49 372 living in the affected area after a disaster, hypertension, diabetes and dyslipidaemia
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51 373 were controlled in the multiple variable analysis. To avoid overfitting, we used four
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3 374 models to adjust confounding variables step by step. The resulting ORs reflected
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5 375 minor changes in the 4 models, suggesting that earthquake experience may be an
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7 376 independent risk factor for the occurrence of depression.
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10 377 Our study has a few limitations. First, substantial time has passed since the earthquake
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12 378 occurred, and we were unable to control for every event or factor. For example, we
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14 379 did not consider other traumatic events, such as traffic accidents, adverse childhood
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16 380 experiences, other bereavement or current psychological stressors, which could have
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18 381 confounded the observed associations. Additionally, the sample was not
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20 382 representative of all survivors of the Tangshan earthquake. We did not include
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22 383 survivors who had died in the past 37 years. Premature death may be related to
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24 384 depression and disease. Meanwhile, in our sample, nearly 20% of the survivors did
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26 385 not live in the earthquake zone 1-2 years after the earthquake. These people left the
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28 386 painful environment and may have worked or attended school elsewhere for several
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30 387 years, which may have largely relieved psychological stress and alleviated the
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32 388 symptoms of depression. Therefore, the potential impacts of the earthquake on
33
34 389 depression may have been underestimated. Third, whether the subjects were taking
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36 390 antidepressants was unknown. Fourth, the cross-sectional design of this study
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38 391 precludes causal inferences. Finally, depression was assessed only once during the
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40 392 study; therefore, we could not exclude the possibility of reverse causality.
41
42 393 The results of our study are very relevant to future research on depression among
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44 394 disaster survivors. For instance, survivors of earthquakes in Japan, Haiti, and China
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46 395 were all affected by high rates of depression in the short term⁵⁹⁻⁶². Although the
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48 396 timing and severity of the disasters, the ethnicity of the affected population, and the
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50 397 living environment of the survivors are different, the stressors caused by disasters are
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52 398 similar. Strengthening community social cohesion can facilitate recovery from
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3 399 disaster trauma^{63 64}. Clinicians and policymakers in public health should direct
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5 400 additional early social support towards high-risk survivors of disasters, a measure that
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7 401 may reduce the incidence of mental health problems, including depression, in disaster
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9 402 zones⁶⁵, even long after the disaster has passed.

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14 404 **CONCLUSIONS**

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17 405 Thirty-seven years after the disasters, earthquake experience was associated with
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19 406 depression among bereaved survivors, women and individuals over 18 years old at the
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21 407 time. Our study provides evidence supporting the hypothesis that the effect of an
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23 408 earthquake on depression persists for at least 37 years.
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10
11 guarantee that all authors have approved the changes in the author list.
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15
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17
18 manuscript. JCY, QHC and BG critiqued the manuscript for important intellectual
19
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21
22 approved the final version of this manuscript.
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34 **Competing interests** None declared.
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37 **Ethics approval** The research was approved by the Ethics Committee of Jidong
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39 Oilfield Staff Hospital.
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42 **Data sharing statement** All data used or analysed in the current study are available
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44 from the corresponding author upon reasonable request.
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Table 1 Population characteristics according to earthquake experience

Characteristics	Overall	No experience (n=4383)	Experience without bereavement (n=543)	Experience with Bereavement (n=98)	<i>P-value</i>
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

Table 2. Odds ratios 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 1-2 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 1-2 years after the earthquake, hypertension, diabetes, and dyslipidaemia.

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3 409 **Figure 1** Odds ratio of depression given earthquake experience, stratified by gender
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6 410 and age at the time of the earthquake.
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8 411 Groups stratified by gender, adjusted for age at the time of the earthquake, smoking
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10 412 status, drinking status, education, income, residence in Tangshan 1-2 years after the
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12 413 earthquake, hypertension, diabetes, and dyslipidaemia. Groups stratified by age at the
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14 414 time of the earthquake, adjusted for gender, smoking status, drinking status, education,
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16 415 income, residence in Tangshan 1-2 years after the earthquake, hypertension, diabetes,
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18 416 and dyslipidaemia.
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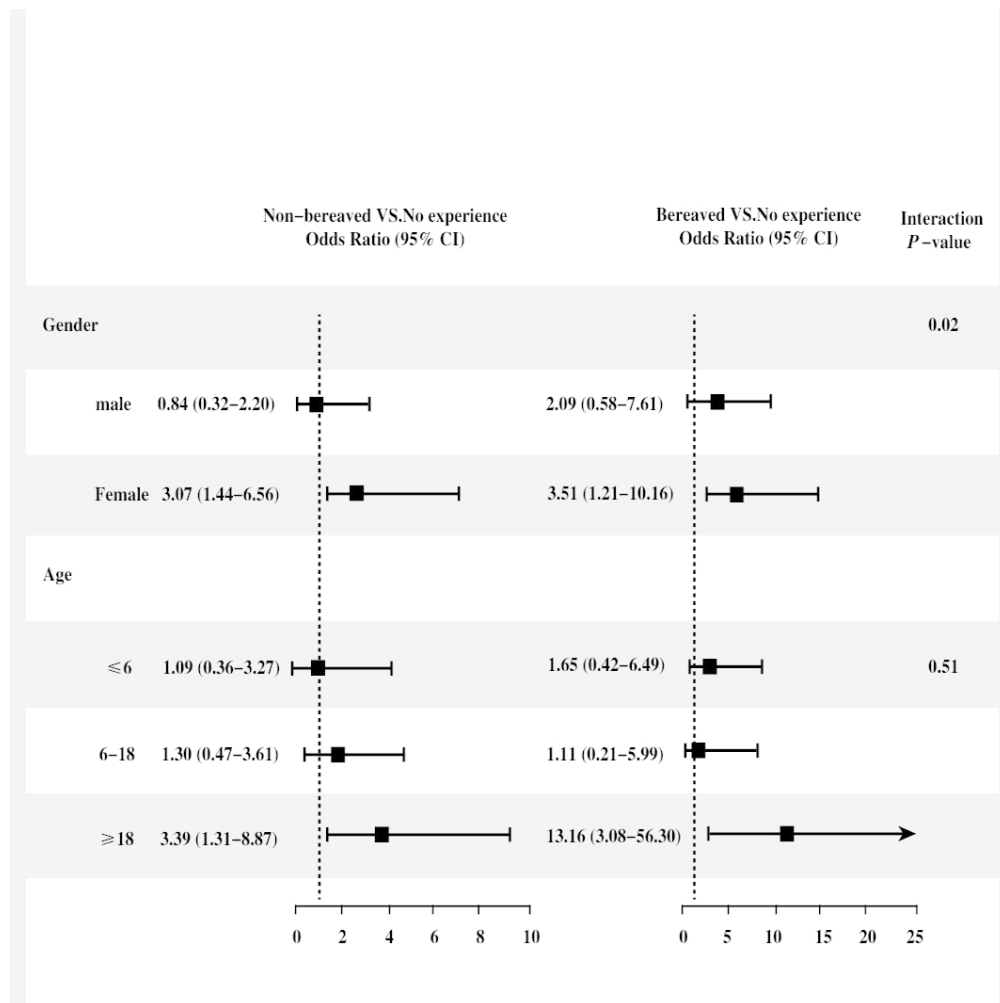


Figure 1 Odds ratio of depression given earthquake experience, stratified by gender and age at the time of the earthquake.

Groups stratified by gender, adjusted for age at the time of the earthquake, smoking status, drinking status, education, income, residence in Tangshan 1-2 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 1-2 years after the earthquake, hypertension, diabetes, and dyslipidaemia.

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The Association between Earthquake Experience and Depression 37 Years after the Tangshan Earthquake: A Cross-sectional Study

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Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Mental health, Public health, Health services research
Keywords:	Depression & mood disorders < PSYCHIATRY, Earthquake, Association, EPIDEMIOLOGY

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3 **1 The Association between Earthquake Experience and Depression 37 Years after**
4 **the Tangshan Earthquake: A Cross-sectional Study**

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3 36 **ABSTRACT**
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5 37 **Objective** To investigate the association between the Tangshan earthquake and
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8 38 depression after 37 years.
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10 39 **Design and setting** A cross-sectional study conducted in Tangshan from 2013 to
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12 40 2014.
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14 41 **Participants** The sample included 5024 participants born before July 28, 1976, the
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16 42 date of the Tangshan earthquake, with available data on their earthquake experiences
17
18 43 and depression 37 years post-earthquake.
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21 44 **Outcomes and variables** The outcome was depression measured using the CES-D.
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23 45 The independent variable was earthquake experience, which was classified into 3
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25 46 groups: no earthquake experience, earthquake experience without bereavement, and
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27 47 earthquake experience with bereavement. Multivariable logistic regression analysis
28
29 48 was used to evaluate the association between earthquake experience and depression
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31 49 after adjusting for gender, age at the time of the earthquake, smoking status, drinking
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33 50 status, education, income, residence in Tangshan 1-2 years post-earthquake,
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35 51 hypertension, diabetes, and dyslipidaemia.
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40 52 **Results** Of the 5024 participants, 641 experienced the Tangshan earthquake, and 98
41
42 53 experienced bereavement due to the earthquake. Thirty-seven years after the
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44 54 earthquake, survivors who had lost relatives during the earthquake were nearly 3
45
46 55 times (OR 2.82, 95% CI 1.24-6.39) as likely to have depression as those who had not
47
48 56 experienced the earthquake, while those who had not lost relatives were 1.69 times as
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50 57 likely (OR 1.69, 95% CI 0.93-3.08). Stratified analyses showed that earthquake was
51
52 58 significantly associated with depression in women with (OR 3.51, 95% CI 1.21-10.16)
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54 59 or without bereavement (OR 3.07, 95% CI 1.44-6.56) but not in men; this association
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56 60 was also significant in individuals over 18 years old at the time of the earthquake with
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3 61 (OR 13.16, 95% CI 3.08-56.3) or without bereavement (OR 3.39, 95% CI 1.31-8.87)
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5 62 but not in individuals less than 18 years old.
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8 63 **Conclusions** Thirty-seven years after the Tangshan earthquake, earthquake
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10 64 experience was associated with depression among bereaved survivors, women and
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12 65 individuals over 18 years old at the time.
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3 **68 Strengths and limitations of this study**
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5 ● 69 The study investigated the long-term risk of depression 37 years after a major
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8 70 earthquake.

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10 ● 71 Participants were stratified by gender and age at the time of the earthquake.

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12 ● 72 We were unable to control for every event or factor, such as adverse childhood
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15 73 experiences, other bereavement or current psychological stressors.

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17 ● 74 Only participants who were still alive 37 years after the earthquake were able to
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20 75 participate in the study.
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76 INTRODUCTION

77 Depression is predicted to be a major reason for disability around the world by 2030,
78 according to the World Health Organization¹. In addition, the chronic and debilitating
79 nature of depression complicates the prognosis of chronic diseases, aggravates various
80 diseases and may lead to suicide²⁻⁴. Evidence shows that depression is related to
81 demographic characteristics, living habits, education, income, and health status⁵⁻⁷.

82 Participants exposed to disasters at an early life stage are at an increased risk of
83 depression in the short term (1-4 years), independent of age, gender, income,
84 education and other confounders⁸⁻¹⁰. Additionally, studies report that some survivors
85 have psychological problems in the immediate aftermath of disaster trauma; most of
86 these reactions abate over time, and only a minority of survivors develop a
87 long-standing disorder^{11 12}. Therefore, long-term evidence is essential to evaluate the
88 effects of disaster on depression.

89 Findings regarding the long-term impact of disasters on mental health have been
90 mixed. Several studies have reported no significant differences^{13 14}, but others have
91 revealed more psychological problems in exposed individuals than in non-exposed
92 individuals for more than a decade after disasters^{10 15 16}. Moreover, evidence shows
93 that such effects are increased if survivors suffer from bereavement^{10 12}. Additionally,
94 the association between earthquakes and depression may vary according to age or
95 gender. Studies indicate that overall levels of psychological symptoms may vary
96 among children, adolescents, and adults due to differences in physiology and
97 cognition^{17 18}. In response to disaster, women appear develop more intense and
98 longer-lasting psychological symptoms than men^{13 19}. However, very few of these
99 studies investigated the long-term effect of earthquakes on depression risk in the
100 Chinese population.

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3 101 Our study provides a suitable setting for investigating the long-term impact of
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5 102 earthquakes on depression in the Chinese population. The Tangshan earthquake,
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7 103 which occurred in 1976, had a magnitude of 7.8 on the Richter scale²⁰. The
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9 104 earthquake caused 242,769 deaths and left 164,851 people severely injured,
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11 105 representing the strongest and deadliest natural disaster in the twentieth century²⁰.
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13 106 Since the earthquake, numerous studies have examined the effects of the event on
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15 107 physical health outcomes. These studies report increased risks of diabetes,
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17 108 cardiovascular disease, and elevated levels of uric acid among survivors of the
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19 109 Tangshan earthquake even at time points more than 30 years later²¹⁻²³. However, no
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21 110 study to date has examined the long-term effect of the Tangshan earthquake on the
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23 111 risk of depression.
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26 112 The aim of our study was to examine the long-term effect of disaster on depression 37
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28 113 years later. We hypothesized that the earthquake-exposed group would be more likely
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30 114 than the non-exposed group to exhibit depression. Furthermore, we expected that
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32 115 bereaved survivors would be more likely to experience depression than non-bereaved
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34 116 survivors. Considering that age and gender may confound the association between
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36 117 earthquake experience and depression, we also performed an analysis stratified by age
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38 118 and gender.
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120 **METHODS**

121 **Study participants**

122 The participants were selected from the Jidong Cohort, an ongoing community-based
123 prospective study in Chinese adults²⁴. The Jidong community is located in the
124 Caofeidian district of Tangshan City, which is approximately 60 km from the
125 epicentre of the Tangshan earthquake. Cluster sampling was used to select

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3 126 participants. From July 2013 to August 2014, a total of 9078 residents in the Jidong
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5 127 community were recruited to participate in the cohort. Data regarding demographic
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7 128 and behavioural characteristics, insomnia, cognition, depression, and biochemical
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9 129 indicators have been collected from this cohort at annual follow-ups since 2013²⁵⁻²⁷.
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11 130 These data were collected using a set of self-administered questionnaires (including
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13 131 the Center for Epidemiological Study and Depression Scale (CES-D)) with the
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15 132 assistance of well-trained research nurses during face-to-face interviews. Biomedical
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17 133 variables were collected by physical examinations and laboratory assessments.
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19 134 Research on this cohort originally examined sub-health and later expanded to examine
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21 135 depression, cardiovascular health, cerebrovascular health and other areas²⁵⁻²⁸.
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23 136 In the current study, we excluded 4054 of the 9078 candidate participants according
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25 137 to the following standards: (1) birth date after July 28th, 1976 (n=4053); (2)
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27 138 incomplete information on relevant earthquake experience (n=1); and(3) missing
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29 139 values in the surveys for the CES-D measurement scale (n=0). Missing data for
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31 140 confounding variables (60 income variables) were imputed with their mean values
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33 141 among these participants. Ultimately, a total of 5024 individuals were included in this
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35 142 cross-sectional study. The participants in the Jidong Cohort are subjected to a physical
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37 143 examination annually, which is paid for by the community. Therefore, the response
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39 144 rate was almost 100%(5024/5025).
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41 145 This study was performed according to guidelines from the Declaration of Helsinki
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43 146 and approved by the Ethics Committee of Jidong Oilfield Staff Hospital. All
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45 147 participants provided written informed consent.
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56 149 **Assessment of earthquake experience**

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3 150 The exposure variable of interest was experience with the earthquake. Earthquake
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5 151 experience and related bereavement were collected through a structured questionnaire.
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7 152 These factors were obtained using the following questions: “Were you in the
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9 153 Tangshan earthquake area in 1976?” and “Did you lose any relatives in the
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11 154 earthquake?”²³ According to the answers to these questions, subjects were classified
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13 155 into 3 groups: no earthquake experience, earthquake experience without bereavement,
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15 156 and earthquake experience with bereavement.
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22 158 **Assessment of current depression**

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24 159 Depressive symptoms were assessed using the CES-D, which was initially developed
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26 160 by the United States National Institute of Mental Health in 1977²⁹. The Chinese
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28 161 version of the CES-D was translated from the international standard version of the
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30 162 CES-D questionnaire in 1985 by two psychiatrists and was specifically designed to
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32 163 screen for depression³⁰. The CES-D questionnaire surveys the frequency of common
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34 164 depressive symptoms over the past week. Each item in the depression assessment
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36 165 section of the questionnaire is scored from 0 (rarely or none of the time, less than one
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38 166 day) to 3 (all of the time, 5–7 days). The four positive statement items (item 4, I felt
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40 167 that I was just as good as other people; item 8, I felt hopeful about the future; item 12,
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42 168 I was happy; item 16, I enjoyed life) are reverse coded to calculate the total score,
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44 169 which ranges from 0 to 60. A cut-off value of ≥ 16 has been widely used to define
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46 170 clinically meaningful depressive symptoms³¹⁻³³. All investigators attended a 3-day
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48 171 training course and were licensed before conducting the CES-D interviews.
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56 173 **Assessment of potential covariates**

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58 174 The selected covariates included factors known to be predictive of depression and/or
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3 175 potentially correlated with earthquake exposure, including age at the time of the
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5 176 earthquake, gender, education, income, smoking status, drinking status, residence in
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7 177 Tangshan 1-2 years after the earthquake, hypertension, diabetes, and dyslipidaemia.
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9 178 Age at the time of the earthquake was defined as a continuous variable and then a
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11 179 categorical variable (“≤6 years”, “6-18 years”, or “≥18 years”). The average monthly
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13 180 income of each family member was categorized as “<¥3000”, “¥3000–5000” or
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15 181 “>¥5,000”. Educational level was classified into three categories: “illiteracy or
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17 182 primary school,” “middle school or high school,” and “university or above.”
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19 183 Residence in Tangshan 1-2 years after the earthquake was classified as “yes” and “no”.
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21 184 Smoking status was classified as “yes” (current smoker or quit<12 months ago) and
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23 185 “no” (non-smoker or quit>12 months ago).” Drinking status was divided into “yes”
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25 186 (current drinking <1 standard servings/day, <2 standard servings/day, 2-4 standard
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27 187 servings/day, ≥5 standard servings/day) and “no” (never drank, drank in the past). A
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29 188 standard serving was defined as 15 g of ethanol. Systolic blood pressure (SBP) and
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31 189 diastolic blood pressure (DBP) were measured twice using a mercury
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33 190 sphygmomanometer with the subject in a seated position. If the difference between
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35 191 the two measurements exceeded 5 mm Hg, an additional reading was taken, and the
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37 192 average of the three readings was used. Hypertension was defined as having a history
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39 193 of hypertension, exhibiting an SBP ≥140 mm Hg or a DBP ≥90 mm Hg, or using
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41 194 antihypertensive medications. The definition of diabetes mellitus was a fasting
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43 195 glucose level ≥7.0 mmol/l (126 mg/dl), current treatment with insulin/oral
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45 196 hypoglycaemic agents or a history of diabetes mellitus. Dyslipidaemia was defined as
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47 197 a history of hyperlipidaemia, a total blood cholesterol level ≥220 mg/dl, a triglyceride
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49 198 level ≥ 150 mg/dl, or use of anti-hyperlipidaemic medications. All measures in this
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51 199 cross-sectional study reflected the current values as of data collection.
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3 200 **Statistical analysis**
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5 201 We first compared the characteristics of individuals according to their earthquake and
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7 202 bereavement experiences (no earthquake experience, earthquake experience without
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9 203 bereavement, and earthquake experience with bereavement) using the chi-squared test
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11 204 for categorical variables and one-way ANOVA or the Kruskal–Wallis test for
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13 205 continuous variables.
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17 206 We used logistic regression to examine the association between earthquake
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19 207 experience and current depression, with "no earthquake experience" as the reference
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21 208 group. Four multivariate models were fitted as follows: Model 1 was the unadjusted
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23 209 model. Model 2 was adjusted for age at the time of the earthquake and gender. Model
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25 210 3 was further adjusted for smoking status, drinking status, education, income, and
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27 211 residence in Tangshan 1-2 years after the earthquake. Model 4 was further adjusted
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29 212 for hypertension, diabetes, and dyslipidaemia.
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33 213 We also used multiple logistic regression to examine the association stratified by
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35 214 gender and age at the time of the earthquake. To evaluate whether the effect of the
36
37 215 earthquake on depression would be modified by gender and/or age at the time of the
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39 216 earthquake, we tested the statistical significance of earthquake \times gender and
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41 217 earthquake \times age at the time of the earthquake as interaction effects in a
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43 218 multiple-adjustment logistic model by applying a post-estimation Wald test to obtain
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45 219 an omnibus P-value for the interactions between earthquake categories and
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47 220 depression.
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51 221 All statistical tests were 2-sided, and results with a P-value <0.05 were considered
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53 222 statistically significant. The analyses were performed in SAS version 9.4 (SAS
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55 223 Institute Inc., Cary, NC, USA).
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225 **Patient and public involvement**

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

229

230 **RESULTS**

231 **Characteristics of the study participants**

232 The characteristics of the participants according to earthquake and bereavement
233 experiences are shown in Table 1. In total, 5024 participants were included in this
234 study; the participants were 50.2% male and ranged in age from 37 to 82 years at the
235 time of data collection. Among all participants, 543 (10.8%) individuals experienced
236 the earthquake without bereavement, and 98 (2.0%) participants lost relatives. The
237 individuals who experienced the earthquake with or without bereavement were
238 younger and were more likely to have lived in Tangshan 1-2 years after the
239 earthquake than those who had not experienced the earthquake (12.1 ± 9.0 , 13.1 ± 9.1 ,
240 and 14.8 ± 9.2 years, respectively, for age; 86.7%, 79.4%, and 1%, respectively, for
241 residence). No differences were found in gender, smoking status, drinking status,
242 education, income, hypertension, diabetes or dyslipidaemia. A higher incidence of
243 depression was observed in the bereaved and non-bereaved earthquake survivors
244 (12.2% (12/98) and 7.2% (39/543), respectively) than in those without earthquake
245 experience (4.9% (215/4383)).

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247 **Association between earthquake experience and depression**

248 Odds ratios (ORs) and 95% confidence intervals (CIs) for the association between
249 earthquake experience and depression are presented in Table 2. The risk of depression

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3 250 in the bereaved subgroup was 2.82 times (OR, 2.82; 95% CI, 1.24-6.39) higher than
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5 251 that in the group with no earthquake experience after adjusting for gender, age at the
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7 252 time of the earthquake, smoking status, drinking status, education, income, residence
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9 253 in Tangshan 1-2 years after the earthquake, hypertension, diabetes, and dyslipidaemia.
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12 254 However, no statistically significant association was found in the non-bereaved group.
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16 256 **Subgroup analysis by gender and age as of the earthquake**

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19 257 In the models stratified by gender, the female subjects in both the bereaved (OR, 3.51;
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21 258 95% CI, 1.21-10.16) and non-bereaved (OR, 3.07; 95% CI, 1.44-6.56) subgroups had
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23 259 an increased risk of depression. In contrast, no significant association was found
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25 260 between earthquake experience and the risk of depression among male subjects in
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27 261 either the bereaved (OR, 2.09; 95% CI, 0.58-7.61) or the non-bereaved (OR, 0.84; 95%
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29 262 CI, 0.32-2.20) subgroup. In the models stratified by age at the time of the earthquake,
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31 263 we found a statistically significant association in individuals over 18 years old
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33 264 whether they had lost relatives in the earthquake (OR, 13.16; 95% CI, 3.08-56.3) or
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35 265 not (OR, 3.39; 95% CI, 1.31-8.87). No statistically significant association was found
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37 266 in survivors under 6 years old whether they had been bereaved (OR, 1.65; 95% CI,
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39 267 0.42-6.49) or not (OR, 1.09; 95% CI, 0.36-3.27), and there was also no significant
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41 268 association in survivors aged between 6 and 18 years whether they had lost relatives
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43 269 (OR, 1.11; 95% CI, 0.21-5.99) or not (OR, 1.30; 95% CI, 0.47-3.61). In addition, we
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45 270 found a statistically significant interaction between gender and depression (P for
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47 271 interaction= 0.02) but no significant interaction between age at the time of the
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49 272 earthquake and depression (P for interaction= 0.51) (Figure 1).
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57 274 **DISCUSSION**

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3 275 In this community-based study, we observed that, even after 37 years, earthquake
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5 276 survivors had a higher risk of depression than those who had not experienced the
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7 277 earthquake. In addition, long-term effects of the earthquake on depression were found
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9 278 among bereaved survivors, women and individuals over 18 years old. This study is
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11 279 the first to investigate the association between earthquake experience and depression
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13 280 37 years after an earthquake.
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17 281 Evidence shows that traumatic experiences in childhood and adolescence may have a
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19 282 determining effect on brain structural development, sympathetic nervous system
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21 283 responsivity, and the hypothalamic–pituitary–adrenal axis, especially in younger
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23 284 children (preschool) and school-age children (late childhood and early adolescence),
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25 285 resulting in a large stress response and some psychological problems¹⁸. Therefore, we
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27 286 classified the participants into age categories of 0-6, 6-18 and older than 18 years to
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29 287 investigate the long-term impact of disaster on mental health during different stages
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31 288 of life. However, statistically significant associations were found only in individuals
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33 289 over 18 years of age. One explanation is that different ages have different needs for
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35 290 social networks. Social networking is associated with the onset of depression³⁴.
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37 291 Children's and adolescents' social needs are met by parental care and family³⁵. Adults,
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39 292 in contrast, need support from social interaction in the neighbourhood, the
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41 293 communities, and the work place in addition to family support³⁶. The advent of the
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43 294 earthquake destroyed the previously stable social networks and economic foundation
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45 295 of the community. Social-network destruction may lead to some mental health
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47 296 disorders. Additionally, survivors under 18 years old recover from disaster more
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49 297 easily than older survivors do. Insensitivity to the nature and meaning of disaster
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51 298 trauma³⁷ and access to mental health intervention in the early post-disaster stages³⁸
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3 299 may contribute to recovery from psychological problems among child and adolescent
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5 300 survivors.

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7 301 With regard to gender, we found a significant association between earthquake
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9 302 experience and depression in women but not in men. Similar results have been found
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11 303 in several previous studies of disaster, indicating that women may be at a higher risk
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13 304 of depression than men when they experienced disasters including large earthquake ¹³
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15 305 ¹⁹. Differences in physiology, personality, social role and rumination between women
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17 306 and men might result in this gender difference in the association between depression
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19 307 and disaster³⁹⁻⁴³. The exact causal factors leading to gender differences in long-term
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21 308 effects of earthquakes remains a big challenge for future researches.

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24 309 Consistent with our findings, a longitudinal study on the Alexander Kielland oil
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26 310 platform collapse shows that survivors have a higher risk of depression than
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28 311 non-exposed individuals 27 years after the disaster¹⁵. Similar results are observed in
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30 312 another longitudinal study with 10 years of follow-up, which indicates that survivors
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32 313 of the Piper Alpha oil platform disaster show a long-lasting increase in mental health
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34 314 problems compared with non-exposed individuals¹⁶. In contrast, two studies indicate
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36 315 that disaster has little long-term effect on depression^{13 14}. The inconsistency of the
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38 316 results may be explained by the severity of the disaster. The Tangshan earthquake
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40 317 caused more damage than the Buffalo Creek dam collapse or the Australian bushfire
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42 318 disaster. The earthquake reduced Tangshan to ruins in a few minutes, with
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44 319 approximately 85% of the buildings collapsed and at least 400,000 casualties^{20 44}. The
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46 320 earthquake afflicted the survivors with not only the loss of their homes but also, more
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48 321 importantly, the tension and fear brought by the disaster itself, the loss of loved ones,
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50 322 the complete destruction of social networks and a sense of despair ^{45 46}. During the
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52 323 long-term urban reconstruction process, all these effects of the disaster might lead to
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3 324 long-term adverse psychological effects on the survivors. In addition, the Tangshan
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5 325 earthquake broke out at the end of the decade of the Cultural Revolution. The
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7 326 consequences of the Cultural Revolution, which include a fragile economic
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9 327 foundation, low economic compensation, lack of societal acknowledgement, and
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11 328 destruction of the health care service network, may have delayed recovery.
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14 329 The long-term effect of disaster on depression seems to depend on traumatic
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16 330 experience. In our study, a statistically significant association between earthquake
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18 331 experience and depression was observed in bereaved survivors but not in
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20 332 non-bereaved survivors 37 years after the earthquake. This finding was consistent
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22 333 with a longitudinal study carried out in Italy showing that exposure to loss and
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24 334 damage during an earthquake confers an additional risk of negative psychological
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26 335 consequences above and beyond living in the earthquake zone¹⁰. Similarly, a
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28 336 longitudinal study 14 years after MS Estonia Disaster indicated that non-bereaved
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30 337 survivors recovered from their posttraumatic stress reactions, while little change was
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32 338 found over that period in the reaction of the bereaved¹². Traumatic bereavement may
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34 339 be associated with increased severity of long-term posttraumatic stress reactions after
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36 340 disasters⁴⁷, which is considered to be involved in the onset of depression⁴.
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38 341 Several plausible explanations may link earthquake exposure to the prevalence of
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40 342 depressive symptoms. Earthquakes can cause tremendous, immediate damage to the
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42 343 environment and even lead to adverse life events such as the death of a family
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44 344 member and related events, thus exerting negative effects on individuals' emotions
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46 345 and resulting in posttraumatic stress disorder (PTSD) after the disaster^{4 12}. PTSD, as a
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48 346 frequent comorbidity of depression^{48 49}, may persist for decades following disaster⁵⁰⁻⁵².
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50 347 These findings suggest that traumatic bereavement might be a common mediating
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52 348 mechanism of both depression and PTSD. The pain of loss in survivors may have
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3 349 neurobiological effects on several brain areas (the frontolimbic and striatal areas)^{47 53}.

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5 350 These areas and the functional connectivity within the fronto-striato-thalamic and
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8 351 default-mode networks have been found to be correlated with the progression of
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10 352 mental health problems and may play important roles in adaptation to trauma^{4 54}. The
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12 353 trauma caused by disasters has a variety of mechanisms. Whether PTSD symptoms
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14 354 further transform into depression or other mental illnesses in the long term will
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17 355 require further exploration.

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19 356 Gender, age at the time of the earthquake, education, income, smoking, drinking,
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21 357 living in the affected area after a disaster, hypertension, diabetes and dyslipidaemia
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23 358 were controlled in the multiple variable analysis. To avoid over fitting, we used four
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25 359 models to adjust confounding variables step by step. The resulting ORs reflected
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28 360 minor changes in the 4 models, suggesting that earthquake experience may be an
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30 361 independent risk factor for the occurrence of depression.

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33 362 Our study has a few limitations. First, substantial time has passed since the earthquake
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35 363 occurred, and we were unable to control for every event or factor. For example, we
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37 364 did not consider other traumatic events, such as traffic accidents, adverse childhood
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39 365 experiences, other bereavement or current psychological stressors, which could have
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41 366 confounded the observed associations. Additionally, the sample was not
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43 367 representative of all survivors of the Tangshan earthquake. We did not include
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45 368 survivors who had died in the past 37 years. Premature death may be related to
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47 369 depression and disease. Meanwhile, in our sample, nearly 20% of the survivors did
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49 370 not live in the earthquake zone 1-2 years after the earthquake. These people left the
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51 371 painful environment and may have worked or attended school elsewhere for several
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53 372 years, which may have largely relieved psychological stress and alleviated the
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55 373 symptoms of depression. Therefore, the potential impacts of the earthquake on
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3 374 depression may have been underestimated. Third, whether the subjects were taking
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5 375 antidepressants was unknown. Fourth, the cross-sectional design of this study
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8 376 precludes causal inferences. Finally, depression was assessed only once during the
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10 377 study; therefore, we could not exclude the possibility of reverse causality.
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12 378 The results of our study are very relevant to future research on depression among
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14 379 disaster survivors. For instance, survivors of earthquakes in Japan, Haiti, and China
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16 380 were all affected by high rates of depression in the short term⁵⁵⁻⁵⁸. Although the
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18 381 timing and severity of the disasters, the ethnicity of the affected population, and the
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20 382 living environment of the survivors are different, the stressors caused by disasters are
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22 383 similar. Strengthening community social cohesion can facilitate recovery from
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24 384 disaster trauma^{59 60}. Clinicians and policymakers in public health should direct
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26 385 additional early social support towards high-risk survivors of disasters, a measure that
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28 386 may reduce the incidence of mental health problems, including depression, in disaster
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30 387 zones⁶¹, even long after the disaster has passed.
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389 **CONCLUSIONS**

40 390 Thirty-seven years after the disasters, earthquake experience was associated with
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42 391 depression among bereaved survivors, women and individuals over 18 years old at the
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44 392 time. Our study provides evidence supporting the hypothesis that the effect of an
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47 393 earthquake on depression persists for at least 37 years.
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10
11 guarantee that all authors have approved the changes in the author list.
12
13

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15
16 XG, YZ and HPH designed the study. XG and YL analysed the data and prepared the
17
18 manuscript. JCY, QHC and BG critiqued the manuscript for important intellectual
19
20 content. XG and YCG conducted the statistical analysis. All authors have read and
21
22 approved the final version of this manuscript.
23
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34 **Competing interests** None declared.
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37 **Ethics approval** The research was approved by the Ethics Committee of Jidong
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39 Oilfield Staff Hospital.
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42 **Data sharing statement** All data used or analysed in the current study are available
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44 from the corresponding author upon reasonable request.
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Table 1 Population characteristics according to earthquake experience

Characteristics	Overall	No experience (n=4383)	Experience without bereavement (n=543)	Experience with bereavement (n=98)	<i>P-value</i>
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)	

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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

Table 2. Odds ratios 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 1-2 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 1-2 years after the earthquake, hypertension, diabetes, and dyslipidaemia.

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3 394 **Figure 1** Odds ratio of depression given earthquake experience, stratified by gender
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5 395 and age at the time of the earthquake.
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7 396 Groups stratified by gender, adjusted for age at the time of the earthquake, smoking
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9 397 status, drinking status, education, income, residence in Tangshan 1-2 years after the
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11 398 earthquake, hypertension, diabetes, and dyslipidaemia. Groups stratified by age at the
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13 399 time of the earthquake, adjusted for gender, smoking status, drinking status, education,
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15 400 income, residence in Tangshan 1-2 years after the earthquake, hypertension, diabetes,
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17 401 and dyslipidaemia.
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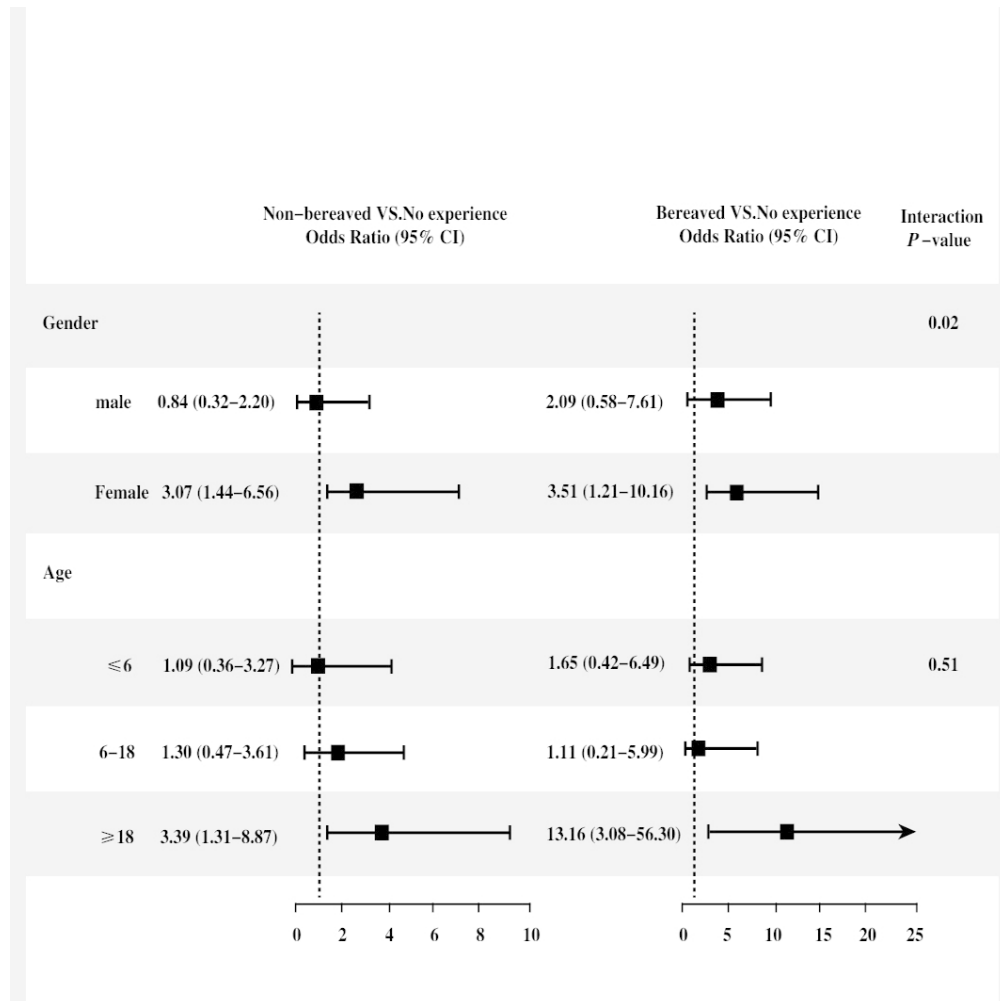


Figure 1 Odds ratio of depression given earthquake experience, stratified by gender and age at the time of the earthquake.

Groups stratified by gender, adjusted for age at the time of the earthquake, smoking status, drinking status, education, income, residence in Tangshan 1-2 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 1-2 years after the earthquake, hypertension, diabetes, and dyslipidaemia.

90x90mm (300 x 300 DPI)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No.	Recommendation	Page No.	Relevant text from manuscript
Title and abstract	1	(a) Indicate the study’s design with a commonly used term in the title or the abstract	1	Line 1-2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	3-4	Line 36-65
Introduction				
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6-7	Line 77-111
Objectives	3	State specific objectives, including any prespecified hypotheses	7	Line 112-118
Methods				
Study design	4	Present key elements of study design early in the paper	8	Line 142
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7-8	Line 122-135
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	8	Line 137-144
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case		
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8-10	Line 150-199
Data sources/measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	8-9	Line 150-171
Bias	9	Describe any efforts to address potential sources of bias	11	Line 206-212
Study size	10	Explain how the study size was arrived at	8	Line 137-144

Continued on next page

Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	11	Line 204-205
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	11	Line 201-223
		(b) Describe any methods used to examine subgroups and interactions	11	Line 213-220
		(c) Explain how missing data were addressed	8	Line 139-142
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed <i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	7-8	Line 125-126
		(e) Describe any sensitivity analyses		NA
Results				
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	12	Line 233-236
		(b) Give reasons for non-participation at each stage	8	Line 137-141
		(c) Consider use of a flow diagram		NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	12	Line 232-245, Table 1
		(b) Indicate number of participants with missing data for each variable of interest	8	Line 139-142
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)		NA
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time <i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure <i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	12	Line 242-245
		(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12-13	Line 248-254, Table 2
		(b) Report category boundaries when continuous variables were categorized	10	Line 179-181, Table 1
Main results	16	(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period		NA

Continued on next page

Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	13	Line 257-272
Discussion				
Key results	18	Summarise key results with reference to study objectives	14	Line 275-280
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	17	Line 362-377
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14-18	Line 281-387
Generalisability	21	Discuss the generalisability (external validity) of the study results	17-18	Line 366-374
Other information				
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	19	Line 404-407

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.