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Earthquake exposure during adolescence and later-life depressive symptoms: A national cross-sectional survey

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ABSTRACT

Background: This study aimed to examine the association between exposure to the 1976 Great Tangshan Earthquake (GTE) in adolescence and later-life depressive symptoms and to investigate the potential mechanisms underlying this association.

Methods: Data were from the 2015 China Health and Retirement Longitudinal Study (CHARLS). The 10-item short form of the Center for Epidemiologic Studies Depression scale (CESD-10) was chosen to measure depressive symptoms. We used the difference-in-difference (DID) method, binary logistic regression models, and multilevel logistic regression models to explore the association of earthquake exposure during adolescence with later-life depressive symptoms. Additionally, multilevel mediation analysis with structural equation modeling (MMSEM) was conducted to investigate potential mechanisms.

Results: We identified that adolescent exposure to earthquakes was related to a lower risk of depressive symptoms in later life (OR = 0.90, P = 0.019; OR = 0.48, P = 0.031; OR = 0.47, P = 0.034, respectively). However, this significant association was observed only in females (OR = 0.83, P = 0.028; OR = 0.46, P = 0.053; OR = 0.42, P = 0.037, respectively). Moreover, social activity participation played a mediating role in the association between exposure to earthquakes in adolescence and later-life depressive symptoms.

Conclusions: We observed a lower risk of depressive symptoms in later life in survivors of earthquake exposure during adolescence. Further, we found the mediating role of social participation in the association between earthquake exposure in adolescence and later-life depressive symptoms, which gives support for the post-traumatic growth (PTG) theory. Our findings imply that, in order to lower the risk of depression in later life following exposure to a natural disaster in adolescence, it is necessary to take into account the buffering effect of social participation.

1. Introduction

Depression is one of the most common mental disorders (Andrews et al., 2005) and can negatively affect the functional ability and quality of life of older people. Among the top 25 leading causes of disability-adjusted life years (DALYs) worldwide in 2019, depression was ranked 13th, accounting for the largest proportion of mental disorder DALYs (Ferrari et al., 2022). It was reported that the number of DALYs caused by depression was 8.579 million in 2017 in China (Ren et al., 2020), imposing a huge burden on the health system and society (Su et al., 2021).

Exposure to life shocks in early life has been shown in previous studies to be associated with health outcomes in later life. However, the findings of them were inconclusive (Gao et al., 2019). On the one hand, exposure to life shocks may damage normal biological conditions, which was shown to increase the risks of health problems (Aoki et al., 2012; Heo et al., 2008; Li et al., 2018; H. W. Xu et al., 2018). On the other hand, exposure to life shocks was found to be related to health improvement. For example, survivors of SARS tended to change their lifestyles, such as participation in more physical examinations and regular physical exercise, fewer diarrhea-related cases, or cognitive health

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Abbreviations

GTE	Great Tangshan Earthquake
CHARLS	China Health and Retirement Longitudinal Study
CESD-10	the Center for Epidemiologic Studies Depression scale
DID	difference-in-difference
MMSEM	multilevel mediation analysis with structural equation modeling
DALYs	disability-adjusted life years
PTG	the posttraumatic growth
PPS	probability proportional to size
ADLs	activities of daily living
ACE	adverse childhood event

(Aguero & Beleche, 2017; Wen et al., 2021; Zou et al., 2021).

The posttraumatic growth (PTG) theory indicates the positive effects of exposure to early life shocks and health outcomes. The PTG suggests that individuals whose development has surpassed the pre-traumatic status quo have favorable changes in cognition, emotion and behavior, even though their posttraumatic growth coexists with psychological distress after trauma (Tedeschi & Calhoun, 1996, 2004). Among these positive changes, health behaviors and more intimate relationships with others are the objective domains of post-traumatic growth (Tedeschi & Calhoun, 1996, 2004; Wen et al., 2021; Zou et al., 2021). Specifically, health behaviors such as social participation and regular physical exercise, and intergenerational relationships have been evidenced in previous research, as the measurements of the PTG, to be the key mediators of the association between life shocks and health (Wen et al., 2021). For example, Wen et al. (2021) found that social participation, regular physical exercise, and intergenerational relationships mediated the link between exposure to SARS and cognitive health. Specifically, survivors of SARS were more likely to develop new insights into life, such as paying more attention to social participation, regular physical exercise and interpersonal relationships, which produced more cognitive health benefits through improvements in the immune system and kinship support.

Some studies have examined the long-term association between life shocks and depressive symptoms (Boe et al., 2011; Falkingham et al., 2020; Li et al., 2018; Pesonen et al., 2007; Zhong et al., 2018), such as the effect of North Sea Oil Rig Disaster in Norway (Boe et al., 2011), the war exposure in the UK (Falkingham et al., 2020, pii), the World War II in Finland (Pesonen et al., 2007), and the famine in China (Li et al., 2018). However, there has been little attention to the association between earthquake exposure in early life, as one of the life shocks or adverse childhood events (ACE), and depressive symptoms in China. Almost all the limited evidence regarding earthquake exposure and depressive symptoms has focused on the short-term effects rather than the long-term effects of earthquake exposure (Geng et al., 2018; Qu et al., 2012; Wang et al., 2020; Xu et al., 2019). To the best of our knowledge, only two studies have examined the long-term association of earthquake exposure with depression. One study concluded that earthquake experience was linked to depression among bereaved survivors 37 years after the Tangshan earthquake (Gao et al., 2019). Another study found that fetal or infancy exposure to the Tangshan earthquake was related to depression in adulthood (Lu et al., 2023). However, both of these two studies were conducted with limited samples and lacked national representativeness, preventing them from establishing causal links. Moreover, they did not explore the possible mechanisms underlying the association between earthquake experiences and depression.

The Great Tangshan Earthquake (GTE) occurred with a magnitude of 7.8 on the Richter scale in Tangshan city of Hebei Province, China, in 1976, which was the worst and greatest natural disaster of the twentieth century, resulting in 242769 deaths and 164851 serious injuries (Sheng, 1987). The GTE offered a unique opportunity to explore the relationship between life shocks and depressive symptoms. Using nationally representative survey data, this study aimed to examine the association between exposure to GTE in adolescence and later-life depressive symptoms and to investigate the possible mechanisms underlying this association. Our study will compensate for the shortcomings of the literature.

2. Methods

2.1. Data and sample

Our data were derived from the 2015 China Health and Retirement Longitudinal Study (CHARLS). CHARLS is a nationally representative study conducted by Peking University every two to three years, modeled after the US Health and Retirement Study (HRS) and other similar aging surveys worldwide. CHARLS used the multistage (county/district-village/community-household), stratified, probability proportional to size (PPS) sampling method in 150 counties and 450 communities in 28 provinces in China in the 2011 baseline survey, totally including 17708 individuals living in 10257 households (the response rate was 80.51%). About 87.15% of the households interviewed for the baseline survey completed at least one survey module in 2015 (Zhao et al., 2020). The CHARLS staff members recruited and trained the interviewers at Peking University, and the face-to-face interviews were conducted using a Computer Assisted Personal Investigation (CAPI) system at the respondents' homes, collecting various information on individuals' socioeconomic status and health as well as community-level characteristics (Zhao et al., 2014).

The flowchart of our sample selection process is shown in Supplementary Fig. 1. Among 21097 participants, this study focuses only on 16196 individuals who were born between 1937 and 1966. The birth cohort (1952–1966) was in their adolescence stage (10–24 years old) of life during the 1976 GTE, and the birth cohort (1937–1951) was at a later stage (25–39 years old) of life during the GTE as compared to the birth cohort (1952–1966). Here, we defined the adolescent as individuals aged 10–24 years during the GTE based on previous research, as this age range more closely aligns with teenage development and common perceptions of this stage of life. This definition allows for sustained investments across a wider range of contexts as compared to the narrower age range of 10–19 years (Sawyer et al., 2018). Then, 912 and 6189 participants were excluded due to missing values in depressive symptoms and earthquake exposure, respectively. Finally, we obtained the final analytical sample of 9095 respondents aged 49–78.

2.2. Measures

2.2.1. Depressive symptoms

We chose the 10-item short form of the Center for Epidemiologic Studies Depression scale (CESD-10) to measure depressive symptoms (Li et al., 2016). Using the CES-D-10 with options varying from 'rarely or none of the time (<1 day)' to 'most or all the time (5–7 days)', CHARLS recorded respondents' answers to the frequency of their moods and behaviors last week. The CESD-10 score ranged from 0 to 30. We defined those having CESD-10 scores higher than 10 as individuals with depressive symptoms (Jin et al., 2019).

2.2.2. Exposure to earthquakes in adolescence

According to previous research, the adolescent was defined as individuals aged 10–24 years (Sawyer et al., 2018). The birth cohort (1952–1966) was defined as the treatment group with exposure to earthquakes during adolescence (10–24 years old during the GTE), and those born between 1937 and 1951 were defined as the control group with exposure to earthquakes at a later stage of life (25–39 years old during the GTE) as compared to the birth cohort (1952–1966), namely, without exposure to earthquakes during their adolescence. Exposure was defined as whether respondents lived in communities affected by the earthquake.

2.2.3. The GTE earthquake severity

CHARLS recorded the three most severe natural disasters or epidemics (such as floods, droughts, fires, earthquakes, SARS, and AIDS) since 1945 within the community in its community questionnaire. In the three most severe natural disasters or epidemics, communities that had at least one history of the 1976 earthquake were defined as the GTE earthquake exposure areas.

2.2.4. Mediators

According to the PTG theory and previous studies (Tedeschi & Calhoun, 1996, 2004; Wen et al., 2021; Zou et al., 2021), we utilized proxy variables, namely social activity participation, regular health behaviors, and intergenerational relationships in adulthood to indicate the presence of PTG, which were selected to be the key mediators in our study. First, participation in social activities indicates whether an individual participated in at least one of the social activities during the prior month, including interacting with friends, playing Ma-jong, chess, cards or going to a community club, going to a sport, social or other kinds of club, taking part in a community-related organization, doing voluntary or charity work, and attending an educational or training course. Second, regular health behaviors suggest whether an individual has ever engaged in any of the activities for at least one year in adulthood, including increasing physical activity, changing the diet, stopping smoking, and decreasing alcohol consumption. Third, the intergenerational relationship in adulthood is referred to as whether an individual had any weekly contact with parents, parents-in-law or children in person or gave care to grandchildren during the last year.

2.2.5. Covariates

Covariates included age in years, sex (male/female), marital status (unmarried/married), activities of daily living (ADLs) (unimpaired/impaired), and life satisfaction (not satisfied/satisfied). Impaired ADLs were defined as having difficulties with any of the following daily activities: bathing, dressing, eating, getting in/out of bed, using the toilet, and controlling urination.

2.3. Statistical analysis

Descriptive statistics were used to present the characteristics of participants and the prevalence of depressive symptoms, and T tests and chi-square tests were conducted to compare the sample characteristics by cohort.

To obtain robust results, we adopted the difference-in-difference (DID) method, binary logistic regression models, and multilevel logistic regression models to explore the association of earthquake exposure during adolescence with the risk of later-life depressive symptoms. The cohort DID method is a quasi-experimental design that obtains an appropriate counterfactual to estimate a causal effect (Guo et al., 2020; Luo et al., 2023). Using the cohort DID method to infer the causal effect of exposure to life shocks has been verified to have good validity and broadly applied in previous studies (Athey & Imbens, 2006; He et al., 2019), such as the effect of famine (P. He, Liu, et al., 2018; (He et al., 2018); H. Xu et al., 2018; Xu et al., 2016), earthquake (Guo et al., 2019), flood (Guo et al., 2020), the SARS epidemic (Guo & Zheng, 2021), war (He et al., 2019; Lee, 2014), and the send-down movement in rural China (Chen et al., 2020; Luo et al., 2023; Ye et al., 2021) on later life health outcomes. The concept of the cohort DID method is to explore geographic variations in earthquake exposure in addition to cohort variations (Xu et al., 2016), specifically examining regional differences in earthquake exposure across different birth cohorts (Guo et al., 2019). The strength of the DID method lies in its better control of unobserved differences between birth cohorts caused by non-earthquake factors (H. Xu et al., 2018), as long as such differences do not vary with the severity of earthquake exposure (Xu et al., 2016).

In our study using the DID method, we estimated the differences between two depressive symptoms: the difference in birth cohorts within the exposed group living in earthquake-affected communities (D1), and the difference in birth cohorts within the unexposed group living in communities unaffected by the earthquake (D2). Our focus was on the estimation of D1-D2. We used the birth cohort to identify whether or not the respondent was exposed to the GTE earthquake during adolescence and used the earthquake exposure status across communities to identify the difference in earthquake exposure across regions in the same birth cohort. The equation of logit regression models with the DID estimator was fitted as follows:

$$Y_{ijk} = \partial_0 + \gamma_j Cohort_j + \theta_k Earthquake_k + \beta_{jk}\left(Cohort_j \times Earthquake_k\right) + \delta X_{ijk} + \varepsilon_{ijk}$$

where Y_{ijk} is the risk of depressive symptoms for individual i of birth cohort j in the community with earthquake exposure status k; β_{jk}, the coefficient of the interaction between birth cohorts and community-level earthquake exposure status, evaluates the effect of adolescent exposure to an earthquake on the risk of depressive symptoms in later life; δX_{ijk} denotes a vector of covariates; and ε_{ijk} is random errors. We controlled for city fixed effects, effectively capturing the characteristics at the city level, and calculated robust standard errors to adjust for sample clustering at the community level. By using the new control cohort (1937–1943) and placebo-treated cohort (1944–1950), we performed a placebo test to examine the validity and robustness of DID estimates. In the binary logistic regression models, standard errors were also clustered at the community level to address possible potential heteroscedasticity and serial correlation problems (Bertrand et al., 2004).

Additionally, multilevel mediation analysis with structural equation modeling (MMSEM) was conducted to investigate potential mechanisms between earthquake exposure in adolescence and the risk of depressive symptoms, disaggregating the direct and indirect pathways of this association.

All models above adjusted for age, sex, marital status, ADLs, and life satisfaction. To address the potential bias due to sample exclusion, using multiple imputation methods by chained equations, we produced five completed datasets to replace missing values in mediators and covariates (White et al., 2011). We set the statistical significance level at a p value of less than 0.05. Stata V.14.0 (StataCorp LP, College Station, Texas) was used for all analyses.

2.4. Ethics approval

All procedures on human subjects were approved by the Ethical Review Committee (IRB00001052–11015). All participants provided written informed consent before they participated in this survey. The study was conducted according to the guidelines of the Declaration of Helsinki.

2.5. Patient and public involvement

It was not appropriate or possible to involve patients or the public in the design, or conduct, or reporting, or dissemination plans of our research.

3. Results

3.1. Characteristics of participants by birth cohort

Table 1 shows the birth cohort-specific characteristics of the participants. The birth cohort (1937–1951) and birth cohort (1952–1966) had different sex compositions, with more males (51.36%) and more females (51.87%), respectively. More participants were married and had

Table 1
Characteristics of participants, by cohort.

Characteristics	Overall (N = 9095)	Birth cohort (1937–1951) (N = 3271)	Birth cohort (1952–1966) (N = 5824)	*P* value
Age, years	60.83 (7.76)	69.40 (4.08)	56.02 (4.50)	<0.001
Sex				
Male	4483 (49.29)	1680 (51.36)	2803 (48.13)	0.003
Female	4612 (50.71)	1591 (48.64)	3021 (51.87)	
Marital status				<0.001
Unmarried	1603 (17.63)	777 (23.75)	826 (14.18)	
Married	7492 (82.37)	2494 (76.25)	4998 (85.82)	
ADLs				<0.001
Unimpaired	7134 (78.44)	2280 (69.70)	4854 (83.34)	
Impaired	1918 (21.09)	990 (30.27)	928 (15.93)	
Missing	43 (0.47)	1 (0.03)	42 (0.72)	
Life satisfaction				0.229
Not satisfied	740 (8.14)	250 (7.64)	490 (8.41)	
Satisfied	8279 (91.03)	2980 (91.10)	5299 (90.99)	
Missing	76 (0.83)	41 (1.25)	35 (0.60)	
Earthquake areas				0.438
Not affected	8890 (97.75)	3192 (97.58)	5698 (97.84)	
Affected	205 (2.25)	79 (2.42)	126 (2.16)	

Note: ADLs = activities of daily living. Birth cohort (1952–1966) indicates persons exposed to the earthquake during adolescence (10–24 years old), and birth cohort (1937–1951) indicates persons exposed to the earthquake at older ages (25–39 years old).

unimpaired ADLs in the birth cohort (1952–1966) than in the birth cohort (1937–1951). Apart from these, both cohorts were similar in terms of life satisfaction (roughly 91.03–91.10% satisfied with life) and earthquake exposure status (approximately 97.58–97.84% residing in communities not affected by earthquake).

3.2. Prevalence of depressive symptoms by birth cohort

Table 2 reports the prevalence of depressive symptoms by birth cohort. The overall prevalence of depressive symptoms was 30.18%, which was a high level in China. A higher prevalence of depressive symptoms was observed in individuals from communities not affected by earthquakes (30.39%) than in those from communities affected by earthquakes (20.98%). Individuals in the birth cohort (1952–1966) in communities affected by earthquakes had the lowest prevalence of depressive symptoms (16.67%). In terms of the prevalence for each cohort categorized by demographic characteristics, males, married people and those with unimpaired ADLs and who were satisfied with life in the birth cohort (1952–1966) had a relatively lower prevalence of depressive symptoms (21.30%, 26.75%, 22.70% and 24.44%, respectively).

3.3. Earthquake exposure and risk of depressive symptoms

Table 3 presents the DID, binary logistic regression and multilevel logistic regression estimates of the relationship between earthquake exposure and the risk of depressive symptoms. By performing a DID analysis, we identified that adolescent exposure to earthquakes was associated with a lower risk of depressive symptoms in later life (OR = 0.90, P = 0.019). This association was robust in our placebo test of the DID model (see Supplementary Table 1). Similar to the pattern of the DID estimates, in the results of the binary logistic regression and multilevel logistic regression, exposure to the GTE was also associated with a decrease in the risk of later-life depressive symptoms for individuals in the birth cohort (1952–1966) (OR = 0.48, P = 0.031; OR = 0.47, P = 0.034, respectively).

Then, we explored the potential heterogeneity of the effects of earthquake exposure by fitting the same models to male and female

Table 2
Prevalence of depressive symptoms, by cohort.

Characteristics	Overall (N = 9095)	Birth cohort (1937–1951) (N = 3271)	Birth cohort (1952–1966) (N = 5824)
Total	2745 (30.18)	1101 (33.66)	1644 (28.23)
Earthquake status			
Non-affected	2702 (30.39)	1079 (33.80)	1623 (28.48)
Affected	43 (20.98)	22 (27.85)	21(16.67)
Sex			
Male	1038 (23.15)	441 (26.25)	597 (21.30)
Female	1707 (37.01)	660 (41.48)	1047 (34.66)
Marital status			
Unmarried	623 (38.86)	316 (40.67)	307 (37.17)
Married	2122 (28.32)	785 (31.48)	1337 (26.75)
ADLs			
Unimpaired	1637 (22.95)	535 (23.46)	1102 (22.70)
Impaired	1105 (57.61)	566 (57.17)	539 (58.08)
Missing	3 (0.07)	0 (0.00)	3 (0.07)
Life satisfaction			
Not satisfied	525 (70.95)	187 (74.80)	338 (68.98)
Satisfied	2187 (26.42)	892 (29.93)	1295 (24.44)
Missing	33 (42.31)	22 (53.66)	11 (31.43)

Note: Birth cohort (1952–1966) indicates persons exposed to the earthquake during adolescence (10–24 years old), and birth cohort (1937–1951) indicates persons exposed to the earthquake at older ages (25–39 years old).

Table 3
Earthquake exposure and risk of depressive symptoms.

	OR (95% CI)	*P* value
DID		
Birth cohorts × earthquake areas		
Birth cohort (1937–1951) and non-affected area (reference)	1.00	
Birth cohort (1952–1966) and affected area	0.90 (0.82, 0.98)	0.019
Binary logistic regression		
Birth cohort (1952–1966)		
Earthquake areas		
Not affected (reference)	1.00	
Affected	0.48 (0.25, 0.94)	0.031
Multilevel logistic regression		
Birth cohort (1952–1966)		
Earthquake areas		
Not affected (reference)	1.00	
Affected	0.47 (0.23, 0.95)	0.034

Note: The models adjusted for age, sex, marital status, ADLs, and life satisfaction. And the DID model also controlled for city fixed effects. DID = difference-in-difference; ADLs = activities of daily living. Birth cohort (1952–1966) indicates persons exposed to the earthquake during adolescence (10–24 years old), and birth cohort (1937–1951) indicates persons exposed to the earthquake at older ages (25–39 years old).

subsamples (see Supplementary Table 2). Based on all results of the DID, logistic regression and multilevel logistic regression models, significantly decreased risks of depressive symptoms following earthquake exposure in adolescence were observed in females (OR = 0.83, P = 0.028; OR = 0.46, P = 0.053; OR = 0.42, P = 0.037, respectively) but not in males (OR = 0.98, P = 0.668; OR = 0.55, P = 0.094; OR = 0.57, P = 0.255, respectively).

Fig. 1 illustrates the pathways between earthquake exposure and the risk of depressive symptoms in the birth cohort (1952–1966). Social activity participation played a mediating role in the association between exposure to earthquakes in adolescence and the risk of depressive symptoms. Specifically, adolescent exposure to the earthquake was positively linked to participation in social activities (OR = 1.14, P = 0.035), which was in turn negatively associated with the risk of depressive symptoms (OR = 0.96, P = 0.001). In addition, adolescent exposure to the earthquake was significantly related to depressive symptoms in a direct way (OR = 0.89, P = 0.021).

4. Discussion

In this study, we took community exposure to earthquakes in adolescence as a life shock and examined its association with depressive symptoms in later life. Using data from the nationally representative survey in China, we observed a lower risk of depressive symptoms in later life in survivors of earthquake exposure during adolescence. In addition, participation in social activities was an important mediator of this long-term association of adolescent exposure to earthquakes with mental health, which gives support for the PTG theory.

Our findings showed that exposure to earthquakes during adolescence was related to a lower risk of depressive symptoms in later life. This conclusion is similar to previous studies. From a life course perspective, exposure to adverse life events during the key stage of life including prenatal, infancy, childhood, and adolescence, has a long-term effect on health outcomes (Ben-Shlomo & Kuh, 2002; Viner et al., 2015). Compared to previous research, we were concerned about the association between earthquake exposure and depressive symptoms in later life, a topic with little attention, especially in China. The existing findings of earthquake exposure and depressive symptoms mostly focused on the immediate or short-term effects for individuals with earthquake exposure (Geng et al., 2018; Qu et al., 2012; Wang et al., 2020; Xu et al., 2019), who have been shown to be more likely to have higher risks of depressive symptoms than individuals with longer recovery from the earthquake (Cenat et al., 2020; Helgeson et al., 2006). Instead, we examined the long-term association between earthquake exposure and depressive symptoms. Previous evidence has indicated that the longer it took individuals to recover from an earthquake, the more time they had to obtain growth and get well from the trauma, ultimately gaining the improvement of mental health (Helgeson et al., 2006; Meyerson et al., 2011; Wolchik et al., 2008; Zhou & Wu, 2018). Evidence shows that a stronger earthquake can produce greater benefits for personal growth (Solomon & Dekel, 2007; Tedeschi & Calhoun, 1996). Thus, survivors of the GTE, the worst and greatest natural disaster of the twentieth century, may have noticeable growth in psychology and behaviors.

In this study, the life stage of earthquake exposure we were concerned about was adolescence (10–24 years old), which is one of the key stages in the life course. Compared to later stages of life, adolescence is a critical and sensitive period when individuals establish their worldviews and are more vulnerable to environmental events (Andersen, 2003; Crews et al., 2007; Good & Willoughby, 2008; Mooney-Leber & Gould, 2018). After experiencing the earthquake, adolescents may undergo a cognitive reframing of the event and develop an intrinsic motivation for personal growth (Joseph & Linley, 2005), which makes them more inclined to experience posttraumatic growth. They exhibit positive psychosocial aspects, such as changes in life priorities and improved relationships with others (Jia et al., 2015; Y. C. Jin, Xu, & Liu, 2014; Tang, 2006), in the aftermath of the earthquake. Individuals exposed to earthquake during adolescence may have more time to recover and are ultimately more likely to experience growth in mental health in later life than those exposed during other older life stages.

Our heterogeneity analysis indicated sex differences in the association of exposure to earthquakes during adolescence with the risk of depressive symptoms in later life. The association was only significant in females but not in males, which may be explained by the sex difference in emotional expression. Compared to males, females may be more willing or better able to publicly express their feelings and re-evaluate the significance of life shocks such as earthquake exposure, thereby exhibiting the symptoms of PTG (Y. Jin, Xu, & Liu, 2014; Tang, 2006; Tedeschi & Calhoun, 2004) and subsequently having a lower risk of mental health problems (Wen et al., 2021). Additionally, social participation as an objective measure of PTG is found to be differentially gendered (Naud et al., 2021). Females exposed to earthquakes may be more likely to participate in social activities (such as interacting with friends and families, and doing voluntary work) than males (Gilmour, 2012; Naud et al., 2021), which in turn allows females to derive more mental health benefits from them (Choi et al., 2021).

As a measure of PTG, social participation has been evidenced in our study to play a mediating role in the association between earthquake exposure during adolescence and later-life depressive symptoms, which supports the PTG theory to some extent. Namely, adolescent exposure to earthquakes increased opportunities for social engagement and subsequently decreased the risk of depressive symptoms in later life (Tedeschi & Calhoun, 1996, 2004). For example, individuals who have experienced earthquakes tend to actively seek strategies such as participation in social activities to better connect with others and live a life with more positive attitudes (Y. Jin, Xu, & Liu, 2014; Tedeschi & Calhoun, 1996). In turn, this personal growth may have a positive impact on mental health through improvements in emotional support and health literacy (Hao, 2008).

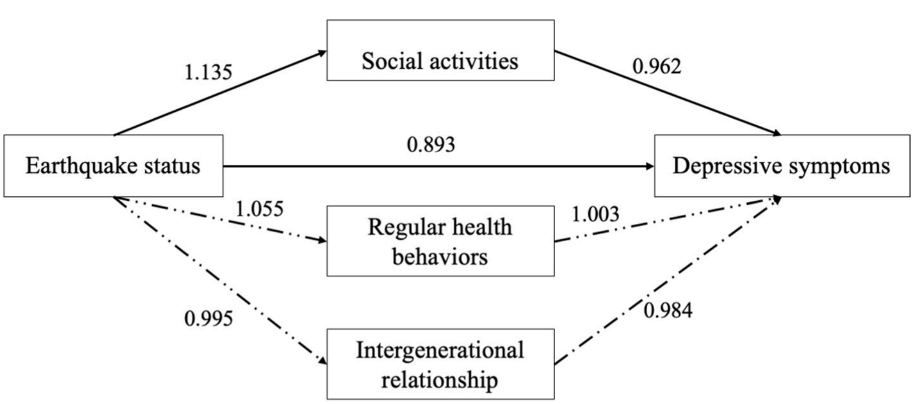

Fig. 1. Multilevel mediation analysis of earthquake exposure and risk of depressive symptoms in birth cohort (1952–1966)
Note: The models adjusted for age, sex, marital status, ADLs, and life satisfaction. The OR estimates are omitted for simplicity. Solid lines indicate significant pathways and dashed lines suggest insignificant pathways in the mediation analysis of earthquake exposure and risk of depressive symptoms. Birth cohort (1952–1966) indicates persons exposed to the earthquake during adolescence (10–24 years old). ADLs = activities of daily living.

4.1. Limitations

Despite being the first to investigate the mechanisms underlying the long-term association of earthquake exposure during adolescence with depressive symptoms, this study has some limitations. First, due to the data constraints, the earthquake exposure variable was not very specific. Future research is needed to specify the exposure variable, such as the severity of exposure. Second, because of the limited available data, we only included three possible mediators. More mediators need to be considered in future studies. Third, the GTE occurred so long ago that we were unable to take into account every event during this period that might confound the current association. Fourth, although we used the DID method to explore the treatment effect of earthquake exposure, the causal relationship could not be drawn due to the cross-sectional design. Fifth, based on the cohort DID method identification, this study was unable to distinguish between the cohort effect and the confounding age effect in a cross-sectional dataset.

Several strengths of this study balance its limitations to some extent. First, our health outcome was measured about 40 years after earthquake exposure. As respondents entered later adulthood, a distinct pattern would perhaps appear, revealing the persistent effect (Ye et al., 2021). Second, our present study expanded on previous studies (Gao et al., 2019; Lu et al., 2023), conducting with large-scale samples that were nationally representative of China. Third, based on the PTG theory, we formally explored the mechanisms behind the linkage of earthquake experiences and depression through MMSEM. Fourth, we applied the DID method, exploiting both cohort and geographical variations in earthquake exposure, which provided a unique opportunity to investigate the impact of exposure to the GTE during adolescence on depression in later life (Guo et al., 2020).

4.2. Conclusion

Earthquake exposure during adolescence was associated with a lower risk of later-life depressive symptoms. In this association, social participation played an important mediating role, which supports posttraumatic growth theory. This study adds to the literature on the long-term association of earthquake exposure with mental health. Our results imply that, in order to lower the risk of depression in later life following exposure to a natural disaster in adolescence, it is necessary to take into account the buffering effect of social participation. Our findings are optimistic since they imply that positive health-related changes are at least conceivable for earthquake survivors. How to maintain beneficial improvements in social and health behaviors is a challenge that still has to be overcome.

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Contributors

YL did the literature review, analysed the data, interpreted the data, wrote the first draft of the manuscript, and revised the manuscript. YNL designed the study, verified and interpreted the data, and revised the manuscript. YTL, YTW and ZL contributed to revision. All authors have read and approved to the published version of the manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2023.101490.

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