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ARTICLE

Cumulative Exposure to Natural Hazards and Mental Health in China: Are Older People More Vulnerable or More Resilient Than Younger and Middle-Aged Adults?

Shuai Zhou[1] · **Crystal Kwan**[1]

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Abstract
Despite the well-documented impacts of single natural hazards like earthquakes, less is known about the psychological adaptation to multiple natural hazards, particularly in rural areas. This study investigated the associations of multiple natural hazards with depression among Chinese adults. Data were retrieved from the China Family Panel Studies conducted during 2010–2018. With a sample of 11,633 Chinese adults, multilevel logistic regression was employed to examine the relationships between natural hazard exposure and depression in the total sample and different age groups. Overall, experiencing four or more natural hazards was associated with a higher risk of being depressed. Regarding hazard type, the number of hydrometeorological and biological hazards was associated with a higher likelihood of depression, whereas the number of geologic and other hazards was related to a lower risk of depression. Middle-aged adults from villages were more likely to be affected by natural hazard exposure than older and younger adults. The findings of this study show that cumulative exposure to natural hazards can generate lasting effects on depressive symptoms, particularly in middle adulthood. The findings also suggest that older adults from rural areas may have accumulated more resilience to mitigate the adverse well-being effects of hazard events. Policies and interventions should enhance disaster awareness and preparation for aging residents from multi-hazard communities.

Keywords Age differences · China · Depressive symptoms · Multi-hazard communities · Natural hazard exposure

1 Introduction

Natural hazards are adverse life events that cause substantial human suffering. In 2021, 367 major natural hazard events were recorded globally, resulting in 10,492 deaths and USD 252 billion direct economic losses (MEM et al. 2022). It is also reported that rapid climate change will lead to more frequent natural hazard events, such as droughts, in the following decades (Masson-Delmotte et al. 2018; UNDRR 2022). As one of the most populated countries, China faces increasing challenges from both natural hazards and demographic aging. Hence, aging-related policies and interventions must be coupled with disaster risk prevention and reduction efforts to promote healthy aging of Chinese adults, especially in high-hazard rural areas.

Most of the current knowledge of disaster adaptation comes from research on survivors of single natural hazards, such as an earthquake, rather than adult residents with cumulative natural hazard exposure (Shin and Ji 2021). Major natural hazards are rapid-onset extreme events that cause massive consequences on numerous communities and require considerable recovery efforts (Tierney 2019). However, natural hazards that occur in rural areas are often small-scale and less intensive but will grow in frequency due to climate change (UNDRR 2022). A combination of multiple natural hazards may generate a compounded effect that chronically undermines livelihood and well-being (Leppold et al. 2022). Risk assessment research has forecasted that the mortality risk and affected population rate in this decade will be comparatively higher in China than in many other countries (Shi et al. 2016). Because little research has examined the well-being of residents in multi-hazard communities and compared affected and non-affected groups

✉ Shuai Zhou
shuai.zhou@connect.polyu.hk

[1] Department of Applied Social Sciences, The Hong Kong Polytechnic University, Hong Kong 999077, China

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(Stroebe et al. 2021), the current understanding of disaster adaptation across hazard contexts and over time is limited. In terms of policy, disaster management and services that focus on short-term response and recovery may remain plagued by the inability to promote human health and livelihoods sustainably.

Moreover, age differences in disaster adaptation are among the most controversial topics in research on disasters and aging. Recent studies with a focus on major hazard events such as the 2008 Wenchuan Earthquake in China (for example, Jia et al. 2010) have predominantly endorsed a narrative of older people's vulnerability, despite the fact that earlier research pinpointed a better adaptation in older groups (for example, Bell 1978; Huerta and Horton 1978; Kilijanek and Drabek 1979; Phifer 1990). Given that rural areas are becoming less age-diverse due to rapid population aging and massive out-migration, disaster-related policymakers and practitioners must raise awareness of the changing age structures in building the adaptive capacity of rural communities. It is worth investigating whether there are age-specific patterns in the mental health effects of multiple hazard exposures.

This study aimed to examine the associations between natural hazard exposure and long-term depression in Chinese adults. Based on a nationally representative survey conducted in China during 2010–2018, this study explored the long-term effects of cumulative exposure to a variety of natural hazards on depression in rural China. The age-related heterogeneity in the effects of natural hazards was also examined. The findings of this study extend and enrich the current understanding of disaster adaptation across both hazard contexts and life stages in rural communities.

2 Literature Review

The following section summarizes research and theoretical models on natural hazard exposure and mental health and age differences in disaster adaptation. Research gaps are identified to facilitate the development of our research hypotheses.

2.1 Cumulative Natural Hazard Exposure and Mental Health

Literature on the impacts of natural hazards has examined a wide range of mental health outcomes, notably post-traumatic stress disorder (PTSD), depression, and anxiety (Goldmann and Galea 2014). Post-traumatic stress disorder was among the most characteristic mental consequences of disaster experiences, with 0% to 70.51% of the disaster-affected population reporting PTSD (Lowe et al. 2019). Moreover, a meta-analysis found that 5.8% to 54.0% of adult residents suffered from clinically depressive disorder after natural hazards and disasters (Tang et al. 2014). Exposure to natural hazards may be associated with increased susceptibility to mental health symptoms in the general population (Goldmann and Galea 2014; Beaglehole et al. 2018), but the risks often change with disaster type. Among the most studied natural hazards are hydrometeorological and geological hazards. Studies have revealed that hurricane-related traumatic events, such as Hurricane Katrina, caused mental disorders among more than half of the respondents (Raker et al. 2019). About 15–35% of people with flood experience exhibited clinical symptoms of PTSD, anxiety, or depression (Mason et al. 2010; Bei et al. 2013). In addition, acute geologic hazards like earthquakes can pose considerable threats to human health and the quality of life (Cui and Han 2019). Evidence from the 2011 Great East Japan Earthquake and Tsunami shows that more than 10% of survivors reported post-traumatic stress and depressive symptoms (Kino et al. 2020, 2021). Nonetheless, biological hazards, such as forest fires that may also cause damage to human health, are insufficiently explored.

Moving beyond single natural hazards, scholarly interest in multi-hazard settings is growing rapidly. This is because several natural hazard events may occur successively or simultaneously (Leppold et al. 2022), affecting residents of a specific region multiple times within a few months/years. Harville et al. (2018) proposed three mechanisms to explain psychological adaptation to multiple natural hazards: (1) cumulative risk, which is defined as a dose-response trend in the risk of worsening mental health following multiple natural hazard events; (2) sensitization, in which people with previous exposure to natural hazards may experience a greater loss in health and well-being after recent disasters; and (3) habituation, where past disaster exposure can foster resilience in people, enhancing their capability to maintain well-being in adverse circumstances. The cumulative risk model has received the most empirical support because exposure to multiple hazards often intensifies the risk of mental health problems among residents in the same region (Harville et al. 2018; Leppold et al. 2022). There is evidence showing that cumulative exposure to hydrometeorological hazards (for example, two or more hurricanes) was related to deteriorated mental well-being (Jacobs and Harville 2015; Garfin et al. 2022). Regarding the sensitization model, a few studies showed that people who suffered losses in previous hurricanes had a higher likelihood of experiencing mental health issues in new hazard settings (Callender et al. 2022; Garfin et al. 2022). In settings with multiple natural hazards, the evidence of habituation has been rarely reported by past studies and warrants further investigation (Harville et al. 2018).

Most research tracks mental health status within a short post-disaster period (Morina et al. 2014) and has frequently

pinpointed the elevated risks in the early stage of a natural hazard-related disaster event. In many cases, psychological symptoms peak within 12 months following disasters (Norris et al. 2002) and then abate with time (Krause 1987; Phifer and Norris 1989). Although much post-disaster evidence demonstrates a trend toward recovery, some research reported a persistent risk of mental health problems among the affected population. A review concluded that mid- or long-term remission rates of PTSD among disaster-affected individuals ranged from 8% to 89% (Morina et al. 2014). For example, one in five residents developed persistent depressive disorders five years after the Great East Japan Earthquake (Kino et al. 2021) or 12 years after Hurricane Katrina (Raker et al. 2019). However, a stable pattern of negative emotions in pre- and post-disaster periods has also been observed (Pruchno et al. 2021; Nagai et al. 2022). Because extant longitudinal studies have merely considered single hazards and yielded mixed findings, we know little about long-term psychological adaptation to multiple natural hazards. In multi-hazard contexts, long-term mental health burden deserves particular attention because cumulative exposure to damage may be more likely than a single hazard to cause socioeconomic losses, interrupt disaster recovery efforts, and lead to chronic stress among residents.

Moreover, it remains unclear whether the effects of multiple natural hazards on depression persist or dilute in the long term. Compared to PTSD, which may be closely linked to peri-disaster traumatic experiences (Goldmann and Galea 2014) and has acute onsets, depression represents more general and enduring episodes of low mood. Moreover, prior PTSD can trigger the development of depression (Ginzburg et al. 2010). Research has shown that the remission rates of depressive symptoms remain much lower than that of PTSD (Raker et al. 2019; Kino et al. 2021), indicating that long-term depression may represent a chronic mental health problem that requires sustainable recovery resources. Unfortunately, no prior research has examined the long-term effects of multiple types of natural hazards on mental health, particularly depression. Therefore, a study on natural hazard exposure and depressive symptoms across disaster contexts (for example, multiple exposures and different hazard types) and over time may be beneficial for improving disaster preparedness in high-risk areas and designing comprehensive disaster policy responses.

2.2 Age Differences in Psychological Adaptation to Natural Hazards

In disaster adaptation research, it remains highly debatable whether older people are more vulnerable or more resilient to post-disaster depressive symptoms than middle-aged and younger adults. The discourse of old-age vulnerability abounds in recent literature because aging-related health decline coupled with social isolation could worsen older adults' ability to cope with environmental risks (Filiberto et al. 2009). For example, studies have emphasized that older age is a risk factor for mental health problems after hurricanes (Lowe et al. 2015) and earthquakes (Jia et al. 2010; Kun et al. 2013). Moreover, it is argued that the secondary effects of natural hazards, such as social disruptions, could incur substantial negative psychological responses among older adults (McClelland et al. 2017).

However, other research on older adults' experience of natural hazards has reported a strikingly distinct pattern. Remarkably, gerontological and disaster research a few decades ago documented an exceptional level of resilience that older adults' mental health was less affected by natural hazards than younger groups (for example, Bell 1978; Huerta and Horton 1978; Kilijanek and Drabek 1979; Phifer 1990). Several scholars have also noted that older adults did not develop severe post-disaster depressive symptoms or PTSD (for example, Strough et al. 2024) and even sustained a higher level of positive emotions (Rafiey et al. 2016) than younger groups. Disaster experience was found to be unrelated to the trajectory of depressive symptoms among older adults in a few recent studies (Kino et al. 2021).

The equivocal findings indicate a lacuna in the current understanding of age-related psychological adaptation to natural hazards. Disaster prevention and recovery interventions can be hampered by the inability to identify high-risk groups. Exposure to multiple natural hazards may increase the enduring risk of mental health problems (Leppold et al. 2022), but such risk is not equally distributed in different age groups. If older adults are more vulnerable to persistent psychological impacts of natural hazards than younger groups, tailored interventions must be delivered to meet their mental health needs. Otherwise, older adults could be mobilized as a key asset for building community-based disaster management capacity. To fill this gap, this research further examined whether the association between multiple natural hazard exposures and depression varies by age group.

2.3 The Current Study

This study examined the long-term associations of cumulative hazard exposure with depression among rural Chinese adults. We focused on participants from rural regions where physical vulnerability may compound with social and institutional constraints. First, compared to urban regions, rural communities, especially in mountainous regions, are more susceptible to the losses of natural hazards. This is because rural residents mainly rely on the agricultural economy and are at an elevated risk of poverty following natural hazards. Second, studies have indicated that rural households tend to have a lower disaster preparedness, particularly in terms of material and action preparedness, than their urban

counterparts (Chai et al. 2021). Third, disaster health management and medical infrastructure remain restricted in rural areas due to inadequate government funding (Zhong et al. 2014). Consequently, multiple natural hazard events may trigger a secondary surge (Runkle et al. 2012) in unmet healthcare needs among rural populations.

According to the cumulative risk model, exposure to multiple natural hazards may cause increased psychological stress. Because the timing of and between exposures was not measured in our data, the sensitization model that assumes a more acute psychological response after subsequent exposures cannot be tested. This study first hypothesized a cumulative risk that "multiple natural hazard exposures are positively associated with depression among Chinese adults" (Hypothesis 1). Moreover, hazard-related impacts are often dependent on the type of natural hazard. It was further hypothesized that "the associations between multiple natural hazard exposures and depression vary by natural hazard type" (Hypothesis 2). Regarding age differences, we tend to endorse the resilience perspective for older adults (Rafiey et al. 2016; Bellet al. 2020) in settings with multiple natural hazards because older people may accumulate more resilience that enables bouncing back from traumatic events. It was anticipated that "older adults' depression may be less affected by multiple natural hazard exposures than that of middle-aged and younger adults" (Hypothesis 3).

3 Methodology

This section describes the research methodology in three parts: (1) the data source and the participants; (2) key measurements; and (3) analytical plans.

3.1 Data and Participants

Data for this study came from the China Family Panel Studies (CFPS). The CFPS is a nationally representative household survey launched by the Institute of Social Science Survey (ISSS) at Peking University. The target sample of CFPS was selected using a multi-stage stratified proportional-to-size sampling strategy. The CFPS baseline survey in 2010 included about 14,960 households from 635 communities in 25 provinces (Xie and Hu 2014). Five follow-up surveys were implemented in 2012 (Wave 2), 2014 (Wave 3), 2016 (Wave 4), 2018 (Wave 5), and 2020 (Wave 6). Trained interviewers approached all family members from the baseline households through either home visits or telephone interviews (a small portion). To ensure data quality, the ISSS conducted three forms of data checks, including statistical checks, audio checks, and telephone callback verification after each wave of data collection. In CFPS Wave 5, 64.5% of the baseline respondents were successfully re-captured.

This study adopted a prospective cohort design together with a non-affected comparison group. It used data from the CFPS Waves 1–5 (Fig. 1) before the outbreak of the COVID-19 pandemic. Individual data were linked with community data by using many-to-one matchings based on community identifiers. Information on community characteristics was obtained through a community survey at the baseline survey and Wave 3. The records on natural hazards were only collected from rural villages in Wave 3 and reported by village cadres. Due to the lack of data, this study cannot include urban communities. Repeated measures of post-disaster depression were retrieved from Waves 4 and 5. Hence, the following inclusion criteria of the adult participants were applied: (1) participants from the baseline survey; (2) aged 18–90 years at baseline; and (3) residing in rural villages during Waves 1 and 3. We excluded participants who had inconsistent community identifiers due to two reasons. First, it is difficult to ascertain the extent of natural hazard exposure among people who moved out of their original villages. Second, residential change induced by the self-selection of movers with better socioeconomic conditions may bias the results of stayers in baseline rural villages. Among the 14,352 eligible adult participants, those who were lost in Waves 4 or 5 (n = 1683), with missing information on depression (n = 760) and independent or control variables (n = 276) were excluded. A total of 11,633 adult participants were included in our analysis.

3.2 Measurements

Depression: The 8-item Center for Epidemiologic Studies Depression (CES-D) Scale (Radloff 1977) was used to assess depression. The respondents were asked about the frequencies of six negative feelings or behaviors (for example, "I find it difficult to do anything") and two positive feelings or behaviors (for example, "I have a happy life"). The responses were rated on a four-point scale from 0 = "never (less than one day)" to 4 = "most of the time (5–7 days)". The total score was obtained by summarizing the scores of eight items after reverse-coding the positive items. It ranged from 0 to 24, with a high CES-D 8 score indicating more depressive symptoms. The scale had a satisfactory internal consistency (Cronbach's alpha = 0.783) in our sample. Following previous research (Briggs et al. 2018), the adult respondents with a score larger than or equal to 9 were clinically classified as being severely depressed, while the remaining (total score < 9) were considered to have a low risk of depression.

Natural hazard exposure: Hazard exposure was assessed by neighborhood reports of natural hazard events, which is deemed more reliable than individual self-reports (Edwards et al. 2021). In the second community survey conducted in 2014, village cadres who were most familiar with neighborhood affairs were asked whether their village

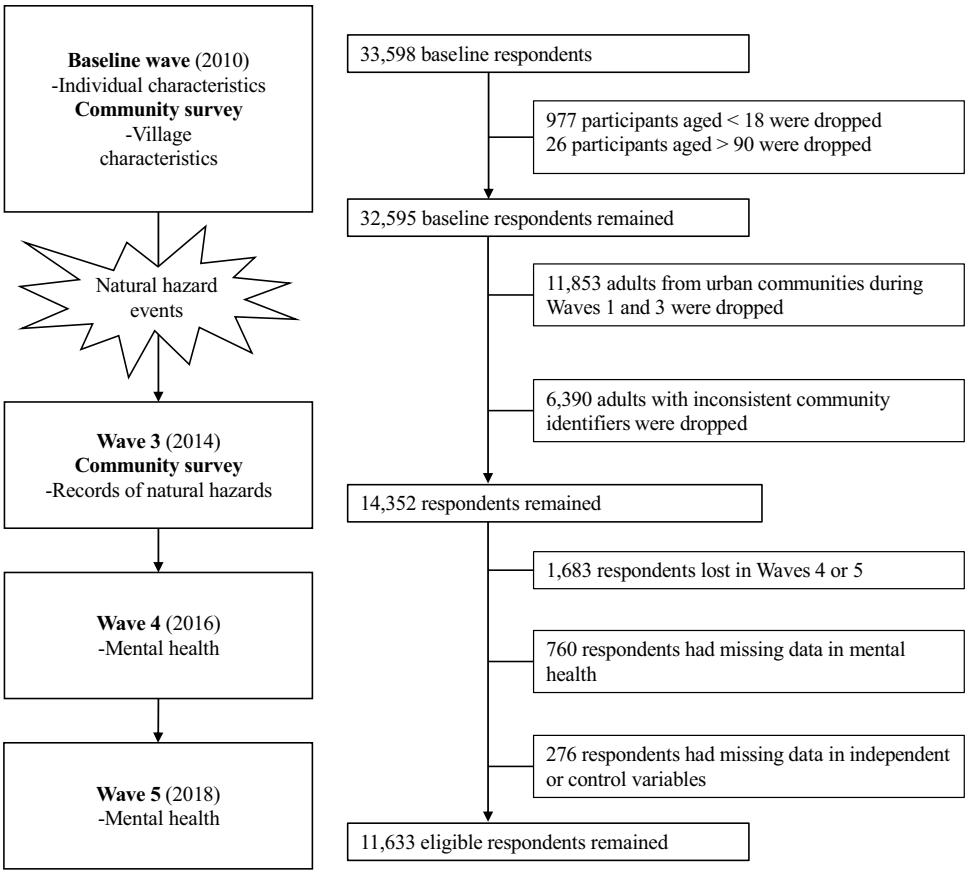

Fig. 1 Flow chart of data collection for the analysis of the cumulative exposure to natural hazards and mental health in China

had experienced any of the following natural hazard events from 1 January 2010 to 31 December 2013: (1) drought; (2) flood; (3) forest fire; (4) frost, hail; (5) typhoon, storm surge; (6) landslide, debris flow; (7) agricultural and forestry pests; (8) earthquake; (9) infectious disease; (10) other hazards; and (11) none of the above. These nine hazards (1–9) are the most frequent forms of natural hazards in China and have uneven distributions across time and space (MEM 2023). This study counted the number of hazard events (Shin and Ji 2021) that affected the community. A categorical variable was created by collapsing the cumulative number of natural hazards into four groups: (1) no hazard; (2) one hazard; (3) two or three hazards; and (4) four or more hazards. In addition, natural hazards could be divided into distinct types according to environmental causes (Shi 2019). We classified the abovementioned events into three major clusters based on the classification and codes for natural hazards of China (GB/T 28921-2012): (1) hydrometeorological hazards, including drought / flood / frost, hail / typhoon, storm surge; (2) biological hazards, including forest fire / agricultural and forestry pests / infectious disease; and (3) geologic or other hazards, consisted of landslide, debris flow / earthquake / other hazards. Three continuous variables were created to measure cumulative exposure to different types of hazards.

Community characteristics: Community geographic characteristics, including natural hazard-prone zone, altitude difference, and geographic region, may affect the susceptibility of residents to natural hazards and their disaster preparedness. The natural hazard-prone zone was a binary variable indicating whether the community was prone to natural hazards (yes versus no). The information about the natural hazard-prone zone was recorded in the community survey at baseline. The community's altitude difference, namely the vertical distance between the highest and lowest altitudes, is a proxy for geographic landscapes. The altitude difference was reported by community cadres at the third wave and recoded into the following categories: 0–10 m, 11–99 m, 100–299 m, 300+ m, and missing, with a larger altitude difference representing greater variations in terrain and climate. The geographic region was a categorical variable, including eastern China, central China, western China, and northeastern China.

Individual characteristics: The participants' demographic, socioeconomic, and health information was collected. Demographics included age (in years), sex (female versus male), ethnicity (Han ethnicity versus minority), marital status (unpartnered versus married/cohabited), and the number of children. Socioeconomic resources comprised education, working status (non-agricultural work,

agricultural work, not working, or missing/unclassified), and personal yearly income. The highest level of education, which included "illiterate/semi-literate," "primary school," "junior high school," "senior high school," "college," "four-year university," "master's degree," and "doctoral degree," was transformed into the number of years of schooling. Personal annual income was collapsed into five groups, including RMB 0–1000 yuan, 1001–4999 yuan, 5000–9999 yuan, 10,000–19,999 yuan, and 20,000+ yuan.[1] Respondents reported whether they had been diagnosed with any chronic diseases (yes versus no) over the past half year. All the individual characteristics were measured at baseline.

3.3 Analytical Strategy

Descriptive analysis was performed to show the demographic and community characteristics, natural hazard exposures, and depression of the sample. Differences in the prevalence of depression between natural hazard exposure groups were tested using the Pearson χ^2 test. Multilevel mixed-effects logistic regression was employed to assess the associations between natural hazard exposure and subsequent depression, given the relatively high clustering structure (person-level intra-class correlation [ICC] = 0.557; community-level ICC = 0.099). Repeated measures of depression at different time points were included at Level 1, individual characteristics were added at Level 2, and natural hazard exposure and community characteristics were included at Level 3. Of interest was the effect size of natural hazard exposure at Level 3.[2] Hence, by specifying random intercepts for each community and participant, the multilevel models could account for the unobserved heterogeneity at both individual and community levels. The regression analyses were performed using the *melogit* command in Stata 17 (StataCorp, College Station, Texas).

We examined the associations of depression with the number of natural hazards and the type of natural hazard exposure in separate models. To examine age differences in the associations between natural hazard exposure and depression, we performed stratified analyses in three subsamples according to current age at Waves 4–5, including younger (< 45 years), middle-aged (45–59 years), and older groups (60 years or above). A survey wave dummy was included to control for temporal heterogeneity. We checked the variance inflation factor score (Mean = 1.59) using multiple linear regression and found no sign of the multicollinearity problem. We also performed several additional analyses to check the sensitivity of the results: (1) we used continuous CES-D 8 score to estimate the mental health risks of natural hazard exposure; (2) we further tested the role of economic status in the link between natural hazard exposure and depression; and (3) we checked the influence of residential mobility on our main results.

4 Results

This section summarizes the characteristics of the participants, the prevalence rates of depression in different hazard exposure groups, and the associations between natural hazard exposure and depression.

4.1 Descriptive Results

Table 1 presents the characteristics of the baseline participants. The mean age of the participants was 44.17 years with a standard deviation of 14.37. The baseline sample had 51.28% of males and 85.89% of Han Chinese. The participants' average level of education was primary school (6.07 years). A vast majority of the participants were married and had children. The participants' economic resources were limited because only 18.33% held non-agricultural jobs and 29.11% had a yearly income of RMB 10,000 yuan (equivalent to USD 1463.91 in 2009) or above. A low proportion of the participants had been diagnosed with a chronic disease (12.29%). Regarding community characteristics, approximately 28.11% of the participants were residing in villages prone to natural hazards. Most of the villages were located at lower altitudes.

Most of the participants were living in communities affected by at least one natural hazard event (77%), with the most prevalent hazards being drought (48.92%), flood (33.84%), and pests (32.51%).[3] The prevalence rate of depression was 21.48% at Wave 4 and slightly increased at Wave 5. As shown in Fig. 2, in the pooled sample, 24.29% of the participants had severe depressive symptoms, with older adults being at the highest risk (28.42%). However, the prevalence rates of depression increased substantially with the number of natural hazards. Of participants from communities affected by four or more hazards, 29.83% developed severe depressive symptoms, which was about 9% higher than that of non-affected participants. The results of Pearson χ^2 indicate that the risk of depression varied by both

[1] The five income groups were equivalent to following income ranges: USD 0–146.39, 146.54–731.81, 731.96–1463.77, 1463.91–2927.68, and 2927.83 or above, based on the annual mean exchange rate of 6.831 in 2009. The average annual income of rural residents in 2009 was RMB 5153 yuan (USD 754.36) according to NBS (2010).

[2] Supplementary note on model specification can be accessed at https://doi.org/10.6084/m9.figshare.25326154.v1.

[3] Supplementary Table S1 for detailed hazard statistics can be accessed at https://doi.org/10.6084/m9.figshare.25326154.v1.

Table 1 Descriptive statistics of the sample ($N = 11{,}633$) used in the analysis of the cumulative exposure to natural hazards and mental health in China

Variable	Mean/percentage	SD
Individual characteristics		
Age (in years, range 18–87)	44.17	14.37
Sex		
Female[a]	48.72%	
Male	51.28%	
Ethnicity		
Han[a]	85.89%	
Minority	14.11%	
Education (in years, range 0–22)	6.07	4.25
Marital status		
Unpartnered[a]	12.47%	
Married/cohabited	87.53%	
Number of children (persons, range 0–10)	1.89	1.23
Working status		
Non-agricultural work[a]	18.33%	
Agricultural work	38.02%	
Not working or missing/unclassified	43.65%	
Personal annual income		
0–1000 yuan (USD 0–146.39)[a]	32.69%	
1001–4999 yuan (USD 146.54–731.81)	21.31%	
5000–9999 yuan (USD 731.96–1463.77)	16.89%	
10,000–19,999 yuan (USD 1463.91–2927.68)	17.56%	
20,000+ yuan (USD 2927.83 or above)	11.55%	
Chronic health condition		
No[a]	87.71%	
Yes	12.29%	
Community characteristics		
Natural hazard-prone zone		
No[a]	71.89%	
Yes	28.11%	
Altitude difference		
0–10 m[a]	28.08%	
11–99 m	14.81%	
100–299 m	16.57%	
300+ m	25.70%	
Missing	14.84%	
Region		
Eastern China	38.67%	
Central China[a]	23.91%	
Western China	30.24%	
Northeastern China	7.18%	
Natural hazard exposure		
Number of natural hazards		
No hazard[a]	22.73%	
One hazard	26.45%	
Two or three hazards	31.96%	
Four or more hazards	18.86%	
Type of natural hazards		
Hydrometeorological hazards (range 0–4)	1.30	1.08
Biological hazards (range 0–3)	0.45	0.69
Geologic or other hazards (range 0–3)	0.23	0.52
Depression		
Depression at Wave 4		
No	78.52%	
Yes	21.48%	
Depression at Wave 5		
No	74.76%	
Yes	25.24%	

Weighted means or proportions are reported

[a]Reference category for subsequent regression analysis

SD standard deviation

natural hazard exposure and age group in Chinese adults ($p_s < 0.001$).

4.2 Regression Results

Table 2 shows the results of the multilevel logistic regression analysis of depression in the total sample and different age groups. In Model 1, exposure to four or more hazards was associated with a higher likelihood of depression (odds ratio [OR] = 1.414, 95% confidence intervals [CI] [1.011,1.978]) in the total sample. The stratified analyses revealed that middle-aged adults who experienced four or more natural hazards were more likely to be depressed (Model 3). Specifically, compared to non-affected middle-aged participants, those exposed to two or three natural hazards were 1.339 times more likely to develop severe depression (CI range from 0.95 to 1.90). In contrast, those exposed to four or more natural hazards were 1.487 times more likely to develop severe depressive symptoms (CI range from 0.97 to 2.23). In Models 2 and 4, the confidence intervals also showed that in frequently disaster-stricken villages, younger adults rather than older adults were at a higher risk of depression. Meanwhile, the ICC values show that the concordance in depression between middle-aged adults was higher than in younger and older people.

The associations between the type of natural hazards and depression were further estimated (Table 3). Model 5 showed that the numbers of hydrometeorological hazards (OR = 1.201, 95% CI [1.083,1.333]) and biological hazards (OR = 1.185, 95% CI [1.007,1.394]) were associated with a higher risk of depression in the total sample. Unexpectedly, the number of geologic hazards was associated with a lower likelihood of being depressed

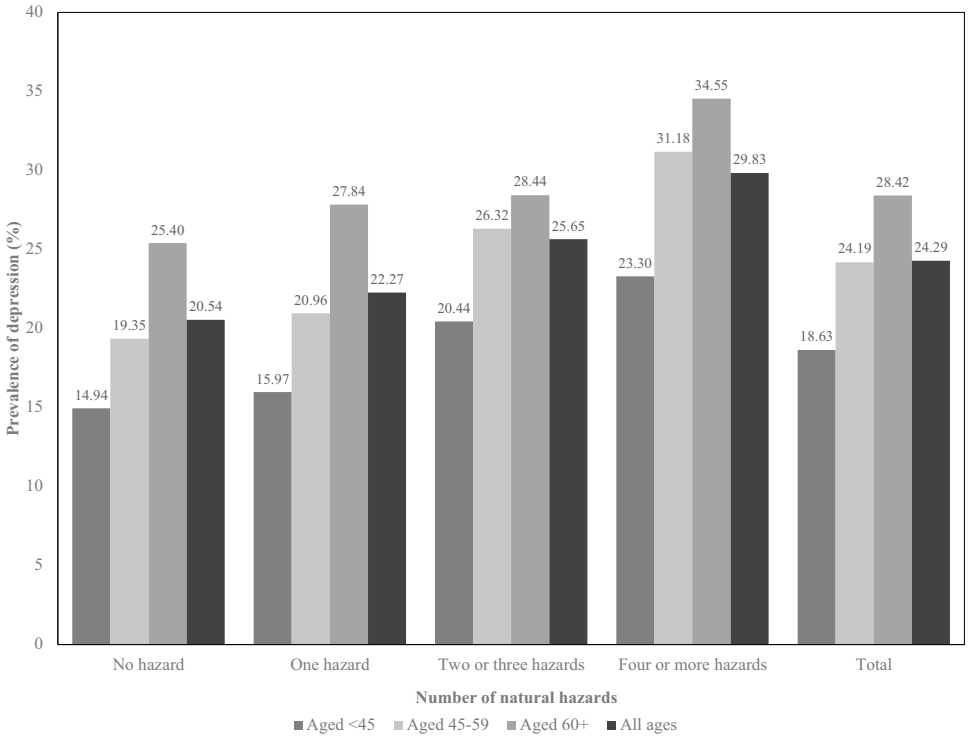

Fig. 2 Prevalence of depression in China during 2016–2018 by natural hazard exposure and age group

Table 2 Associations between number of natural hazards and subsequent depression in 2016–2018 (multilevel mixed-effects logistic models) in China

Fixed Effects	Model 1: Total Sample		Model 2: Aged < 45		Model 3: Aged 45–59		Model 4: Aged 60+	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Number of natural hazards (ref.: No hazard)								
One hazard	1.006	[0.762,1.329]	1.056	[0.705,1.583]	0.916	[0.636,1.321]	1.040	[0.735,1.472]
Two or three hazards	1.181	[0.904,1.543]	1.237	[0.842,1.816]	1.339	[0.945,1.898]	0.976	[0.698,1.366]
Four or more hazards	1.414*	[1.011,1.978]	1.340	[0.841,2.134]	1.487	[0.968,2.285]	1.257	[0.812,1.945]
Controls	✓		✓		✓		✓	
$N_{person-year}$	20,238		5034		8071		7133	
N_{person}	11,633		3140		4667		4373	
$N_{community}$	345		333		338		328	
ICC_{person}	0.503		0.456		0.514		0.505	
$ICC_{community}$	0.070		0.060		0.079		0.071	
AIC	20,223.960		4547.148		8106.031		7778.692	
BIC	20,445.590		4729.820		8301.920		7971.122	
Log likelihood	− 10,083.980		− 2245.574		− 4025.015		− 3861.346	

Control variables included community (natural hazard-prone zone, altitude difference, and region) and individual (age, sex, ethnicity, education, marital status, number of children, working status, personal income, and chronic health condition) characteristics and survey wave

*$p < 0.05$

OR odds ratio, *CI* confidence intervals, *ICC* intraclass correlation, *AIC* Akaike's information criteria, *BIC* Schwarz's Bayesian information criteria

(OR = 0.637, 95% CI [0.519,0.783]). In both younger and older adults, the number of hydrometeorological hazards ($OR_{younger}$ = 1.227, 95% CI [1.059,1.423]; OR_{older} = 1.161, 95% CI [1.012,1.332]) was associated with a higher risk of being depressed, whereas the number of geologic hazards ($OR_{younger}$ = 0.584, 95% CI [0.441,0.772]; OR_{older} = 0.712, 95% CI [0.536,0.945]) reduced the risk of depression. In the middle-aged group, all three types of natural

Table 3 Associations between type of natural hazards and subsequent depression in 2016–2018 (multilevel mixed-effects logistic models) in China

Fixed effects	Model 5: total sample		Model 6: aged < 45		Model 7: aged 45–59		Model 8: aged 60+	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Type of natural hazards								
Hydrometeorological hazards	1.201***	[1.083,1.333]	1.227**	[1.059,1.423]	1.184*	[1.034,1.356]	1.161*	[1.012,1.332]
Biological hazards	1.185*	[1.007,1.394]	1.120	[0.898,1.398]	1.334**	[1.077,1.652]	1.101	[0.887,1.366]
Geologic or other hazards	0.637***	[0.519,0.783]	0.584***	[0.441,0.772]	0.612***	[0.470,0.797]	0.712*	[0.536,0.945]
Controls	✓		✓		✓		✓	
$N_{person-year}$	20,238		5034		8071		7133	
N_{person}	11,633		3140		4667		4373	
$N_{community}$	345		333		338		328	
ICC_{person}	0.500		0.450		0.510		0.504	
$ICC_{community}$	0.063		0.045		0.070		0.069	
AIC	20,199.39		4530.393		8090.325		7770.849	
BIC	20,421.02		4713.064		8286.213		7963.279	
Log likelihood	− 10,071.7		− 2237.196		− 4017.162		− 3857.425	

Control variables included community (natural hazard-prone zone, altitude difference, and region) and individual (age, sex, ethnicity, education, marital status, number of children, working status, personal income, and chronic health condition) characteristics and survey wave

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

OR odds ratio, *CI* confidence intervals, *ICC* intraclass correlation, *AIC* Akaike's information criteria, *BIC* Schwarz's Bayesian information criteria

hazards were found to be associated with depression. Notably, the number of biological hazards (OR = 1.334, 95% CI [1.077,1.652]) was primarily related to middle-aged adults' depression.

4.3 Robustness Analyses

Several further analyses were performed to check the sensitivity of our main results and enrich the findings.[4] First, we estimated the association of individual natural hazards with depression. In addition, we conducted linear regression and negative binomial regression analyses to estimate the associations between natural hazard exposure and the continuous CES-D 8 score. Third, we further estimated the influence of economic status on the link between natural hazard exposure and depression and found that multiple hazard exposures only increased the risk of rural residents from below-median income families, but the negative effect of geologic hazards on depression persisted across household income groups. In our main study, participants who had moved out of the villages were excluded. We estimated whether residential mobility might affect our results. Although natural hazards in original villages could affect residential mobility, the psychological effects of hazard events did not spill over to movers. The results of robustness analyses remained generally consistent with our main results and reaffirmed that older adults were less likely to be negatively affected by natural hazard exposure than younger and middle-aged adults.

5 Discussion

Given the rising risks of multiple natural hazards (Shi et al. 2016), this study investigated the long-term associations between cumulative natural hazard exposure and depression using a nationally representative sample of Chinese adults. It found that exposure to multiple natural hazards was related to a higher risk of depression. Moreover, natural hazards were differentially associated with depression, with hydrometeorological and biological hazards increasing the likelihood of depression and geologic hazards lowering the risk of depression. Furthermore, we investigated whether the associations between natural hazard exposure and depression were conditioned on life stages. Our findings show that older adults were less negatively affected by natural hazard exposure than middle-aged and younger adults.

By reconciling the debates on the mental health effects of natural hazard-related disaster exposure, this study innovatively made three key contributions to the disaster literature and aging research. The first main finding relates to the long-lasting imprints of multiple natural hazard exposures on Chinese adults' depression (hypothesis

[4] Additional results can be accessed at https://doi.org/10.6084/m9.figshare.25326154.v1.

1). Using neighborhood reports of natural hazard events, we found that multiple natural hazards (that is, four or more events) may be more likely to induce persistent psychological impacts in China. One-off exposure to natural hazards may not cause longitudinal psychological impacts, probably because of small-scale recovery efforts. Frequent and diversified occurrences of natural hazards could evoke a cumulative risk for depression (Harville et al. 2018). With multiple exposures to natural hazards, people may be more likely to endorse disengagement coping strategies (Shin and Ji 2021) and face emergent issues that undermine family functioning, such as food insecurity and domestic violence (Edwards et al. 2021). This may imply that chronic overexposure to natural hazards may deplete community residents' resilience resources and endanger their individual and family well-being. Although our supplementary analyses using the relocated sample revealed that moving out may be an effective strategy in response to disasters, residential change may be unaffordable for many rural residents and present barriers to the pursuit of aging in place. Moreover, we observed that the negative effects of natural hazard exposure appeared to be concentrated in people from low-income families. Therefore, sustainable and targeted disaster risk management and recovery interventions may be necessary for rural residents, especially those from lower economic groups and multi-hazard areas, to protect their mental health and strengthen community-level support facilities.

However, our results show that the well-being effects of natural hazards varied by the type of exposure, lending support to hypothesis 2. On the one hand, hydrometeorological and biological hazards were detrimental to mental health. Typhoons, frost and hail events, pests, and infectious diseases were harmful to the participants' mental health. Instead of causing substantial social disruptions, these natural hazards often bring severe losses to rural communities' agricultural economy. Unexpectedly, floods and droughts, which are among the most prevalent forms of natural hazards, were unrelated to Chinese adults' depression. This may be because rural residents may have accumulated knowledge and skills to cope adaptively with these hazards. On the other hand, geologic and other hazards were found to be associated with fewer depressive symptoms among adults in rural China as opposed to survivors from major seismic events in other studies (for example, Kino et al. 2020). As acute forms of natural hazards, landslides and earthquakes may cause housing damage and attract wider attention from the public and governmental agencies. Consequently, exposure to geologic and other hazards may increase the opportunity for receiving considerable governmental support, particularly in the form of poverty alleviation. Because there were few significant geologic disasters in the study regions, policy responses after moderate seismic events may preserve and even improve rural residents' mental health. The findings suggest that research on the cumulative effects of natural hazards should not only focus on the total number of hazards but also the type of hazard exposure and associated changes.

Regarding age differences, our results support hypothesis 3 and show that natural hazards had minimal deleterious influences on older adults' depressive symptoms. The findings are generally consistent with previous studies (Bell et al. 2019; Shin and Ji 2021), showing that older adults may have accumulated exceptional resilience following natural hazards. Given previous evidence of the short-term decline in mental health and life satisfaction of middle-aged and older Chinese adults (Zhang et al. 2022), the absence of associations between the number of natural hazards and depression in our study may indicate that most older adults maintained or recovered their psychological well-being in adverse situations, in line with the habituation model (Harville et al. 2018). Because in closely knitted rural Chinese communities, older adults may be more likely to build resilience resources, such as trust and risk perception (Xue et al. 2021), which could reduce their hazard-related stress. Nonetheless, as warned by Prohaska and Peters (2019), researchers and policymakers should by no means underestimate the threats of natural hazards to older adults' lives over time. Our results show that a higher risk of depression existed among older adults exposed to hydrometeorological hazards, such as frost and hail. Because of sustained engagement in farming activities in later life, rural older adults may develop worries about their livelihoods. Like older adults, younger adults were also marginally affected by natural hazards. In contrast to prior mixed findings of younger adults' post-disaster well-being (Kun et al. 2013; Rafiey et al. 2016), we deem that young people in rural China may have a lower susceptibility to depression because they can acquire disaster-related support from older relatives. More importantly, the increased opportunity for labor mobility may reduce the risk of direct exposure to natural hazards among younger adults.

Moreover, this study reaffirmed that the well-being effects of natural hazards were more salient among middle-aged adults in rural areas. According to the burden hypothesis (Kwan and Walsh 2017; Cherry et al. 2011), middle-aged adults struggling with multiple responsibilities for their families may be caught in more severe hazard-related stress. Especially, biological hazards could increase depression among middle-aged adults because they may suffer from exacerbated economic hardship due to the damage to agricultural production (Zhang et al. 2022). However, the adaptation to multiple hazards may take longer periods for middle-aged adults than for other age groups. In the context of life transitions, the findings imply that natural hazards may pose considerable threats to the well-being of middle-aged adults. Therefore, the promotion of healthy aging in mid-later life should mitigate the risk of cumulative hazard

exposure and improve the health and livelihoods of middle-aged residents in rural regions. Further, future areas of research and practice should focus on how older adults can play a contributive role in building the resilience of their middle-aged counterparts experiencing multiple hazards.

6 Limitations

There are a few cautions that should be exerted when interpreting the findings. First, we cannot explore longitudinal well-being changes because of the lack of consistent pre-disaster outcome measures in earlier waves of the survey. This study of the lasting well-being effects of natural hazard exposure may underestimate the complexity of the adaptation process. Future longitudinal research on mental health trajectories at various phases of natural hazards will be valuable for understanding the patterns of disaster adaptation. Second, our measure of natural hazard exposure did not assess the timing, frequency, and magnitude of each hazard exposure as well as associated economic losses. The operationalization of hazard-related losses may be extremely challenging in the context of multiple hazards. Fellow scholars could develop comprehensive instruments to capture the experiences and impacts of natural hazards. Third, although we examined age differences, the mechanisms that differentiate the well-being effects of natural hazards between different age groups remain unclear. Qualitative research on disaster-related psychosocial needs and resilience resources of middle-aged and older adults could enrich and extend the knowledge of aging-related vulnerability and resilience in context.

7 Conclusion

The present study revealed that natural hazards were associated with the depressive symptoms of Chinese adults, particularly in middle adulthood, over the long term. The findings indicate that the investigation of post-disaster well-being should take into consideration multiple natural hazard events and the type of natural hazard exposure. Moreover, the evidence of age differences in the disaster context provides new avenues for policies and interventions to improve disaster preparedness and facilitate disaster recovery in rural regions prone to natural hazards. Notably, social work and psychological services could be designed and delivered (specifically focused on utilizing the strengths and assets of older adults) to support long-term adaptation among middle-aged adults from rural areas, who may be at higher risk than other age groups of chronic stress resulting from exposure to multiple natural hazards.

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References

Beaglehole, B., R.T. Mulder, C.M. Frampton, J.M. Boden, G. Newton-Howes, and C.J. Bell. 2018. Psychological distress and psychiatric disorder after natural disasters: Systematic review and meta-analysis. *The British Journal of Psychiatry* 213(6): 716–722.

Bei, B., C. Bryant, K.M. Gilson, J. Koh, P. Gibson, A. Komiti, H. Jackson, and F. Judd. 2013. A prospective study of the impact of floods on the mental and physical health of older adults. *Aging & Mental Health* 17(8): 992–1002.

Bell, B.D. 1978. Disaster impact and response: Overcoming the thousand natural shocks. *The Gerontologist* 18(6): 531–540.

Bell, S.A., H. Choi, K.M. Langa, and T.J. Iwashyna. 2019. Health risk behaviors after disaster exposure among older adults. *Prehospital and Disaster Medicine* 34(1): 95–97.

Bell, S.A., J. Horowitz, and T.J. Iwashyna. 2020. Health outcomes after disaster for older adults with chronic disease: A systematic review. *The Gerontologist* 60(7): e535–e547.

Briggs, R., D. Carey, A.M. O'Halloran, R.A. Kenny, and S.P. Kennelly. 2018. Validation of the 8-item Centre for Epidemiological Studies depression scale in a cohort of community-dwelling older people: Data from The Irish Longitudinal Study on Ageing (TILDA). *European Geriatric Medicine* 9(1): 121–126.

Callender, R., J.M. Canales, C. Avendano, E. Craft, K.B. Ensor, and M.L. Miranda. 2022. Economic and mental health impacts of multiple adverse events: Hurricane Harvey, other flooding events, and the COVID-19 pandemic. *Environmental Research* 214: Article 114020.

Chai, L., Y. Han, Z.Q. Han, J.W. Wei, and Y.D. Zhao. 2021. Differences in disaster preparedness between urban and rural communities in China. *International Journal of Disaster Risk Reduction* 53: Article 102020.

Cherry, K.E., J.S. Brown, L.D. Marks, S. Galea, J. Volaufova, C. Lefante, L.J. Su, and D.A. Welsh et al. 2011. Longitudinal assessment of cognitive and psychosocial functioning after Hurricanes Katrina and Rita: Exploring disaster impact on middle-aged, older, and oldest-old adults. *Journal of Applied Biobehavioral Research* 16(3–4): 187–211.

Cui, K., and Z. Han. 2019. Association between disaster experience and quality of life: The mediating role of disaster risk perception. *Quality of Life Research* 28: 509–513.

Edwards, B., M. Gray, and J. Borja. 2021. The influence of natural disasters on violence, mental health, food insecurity, and stunting in the Philippines: Findings from a nationally representative cohort. *SSM—Population Health* 15: Article 100825.

Filiberto, D., E. Wethington, K. Pillemer, N. Wells, M. Wysocki, and J.T. Parise. 2009. Older people and climate change: Vulnerability and health effects. *Generations* 33(4): 19–25.

Garfin, D.R., R.R. Thompson, E.A. Holman, G. Wong-Parodi, and R.C. Silver. 2022. Association between repeated exposure to hurricanes and mental health in a representative sample of Florida residents. *JAMA Network Open* 5(6): Article e2217251.

Ginzburg, K., T. Ein-Dor, and Z. Solomon. 2010. Comorbidity of posttraumatic stress disorder, anxiety and depression: A 20-year longitudinal study of war veterans. *Journal of Affective Disorders* 123(1–3): 249–257.

Goldmann, E., and S. Galea. 2014. Mental health consequences of disasters. *Annual Review of Public Health* 35: 169–183.

Harville, E.W., A. Shankar, C. Dunkel Schetter, and M. Lichtveld. 2018. Cumulative effects of the Gulf oil spill and other disasters on mental health among reproductive-aged women: The Gulf resilience on women's health study. *Psychological Trauma: Theory, Research, Practice and Policy* 10(5): 533–541.

Huerta, F., and R. Horton. 1978. Coping behavior of elderly flood victims. *The Gerontologist* 18(6): 541–546.

Jacobs, M.B., and E.W. Harville. 2015. Long-term mental health among low-income, minority women following exposure to multiple natural disasters in early and late adolescence compared to adulthood. *Child & Youth Care Forum* 44(4): 511–525.

Jia, Z.B., W.H. Tian, W.Z. Liu, Y. Cao, J. Yan, and Z.S. Shun. 2010. Are the elderly more vulnerable to psychological impact of natural disaster? A population-based survey of adult survivors of the 2008 Sichuan Earthquake. *BMC Public Health* 10: Article 172.

Kilijanek, T.S., and T.E. Drabek. 1979. Assessing long-term impacts of a natural disaster: A focus on the elderly. *The Gerontologist* 19(6): 555–566.

Kino, S., A.D. Jun, K. Kondo, and I. Kawachi. 2020. Long-term trends in mental health disorders after the 2011 Great East Japan Earthquake and Tsunami. *JAMA Network Open* 3(8): Article e2013437.

Kino, S., A.D. Jun, K. Kondo, and I. Kawachi. 2021. Persistent mental health impacts of disaster—Five-year follow-up after the 2011 Great East Japan Earthquake and Tsunami: Iwanuma Study. *Journal of Psychiatric Research* 136: 452–459.

Krause, N. 1987. Exploring the impact of a natural disaster on the health and psychological well-being of older adults. *Journal of Human Stress* 13(2): 61–69.

Kun, P., X. Tong, Y. Liu, X. Pei, and H. Luo. 2013. What are the determinants of post-traumatic stress disorder: Age, gender, ethnicity or other? Evidence from 2008 Wenchuan Earthquake. *Public Health* 127(7): 644–652.

Kwan, C., and C.A. Walsh. 2017. Seniors' disaster resilience: A scoping review of the literature. *International Journal of Disaster Risk Reduction* 25: 259–273.

Leppold, C., L. Gibbs, K. Block, L. Reifels, and P. Quinn. 2022. Public health implications of multiple disaster exposures. *The Lancet Public Health* 7(3): e274–e286.

Lowe, S.R., L. Sampson, O. Gruebner, and S. Galea. 2015. Psychological resilience after Hurricane Sandy: The influence of individual- and community-level factors on mental health after a large-scale natural disaster. *PLoS One* 10(5): e0125761.

Lowe, S.R., J.L. Bonumwezi, Z. Valdespino-Hayden, and S. Galea. 2019. Posttraumatic stress and depression in the aftermath of environmental disasters: A review of quantitative studies published in 2018. *Current Environmental Health Reports* 6(4): 344–360.

Mason, V., H. Andrews, and D. Upton. 2010. The psychological impact of exposure to floods. *Psychology, Health & Medicine* 15(1): 61–73.

Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, et al. (eds.). 2018. *Global warming of 1.5°C.* Cambridge: Cambridge University Press. https://www.ipcc.ch/sr15/chapter/spm/. Accessed 26 Jan 2023.

McClelland, E., R. Amlôt, M.B. Rogers, G.J. Rubin, J. Tesh, and J.M. Pearce. 2017. Psychological and physical impacts of extreme events on older adults: Implications for communications. *Disaster Medicine and Public Health Preparedness* 11(1): 127–134.

MEM (Ministry of Emergency Management of China). 2023. Basic information on natural disasters in 2022. Beijing: Ministry of Emergency Management. https://www.mem.gov.cn/xw/yjglbgzdt/202301/t20230113_440478.shtml. Accessed 13 Jan 2023.

MEM (Ministry of Emergency Management of China), Beijing Normal University, National Disaster Reduction Centre of China, and International Federation of Red Cross and Red Crescent Societies. 2022. 2021 global natural disaster assessment report. https://www.preventionweb.net/publication/2021-global-disaster-assessment-report. Accessed 26 Jan 2023.

Morina, N., J.M. Wicherts, J. Lobbrecht, and S. Priebe. 2014. Remission from post-traumatic stress disorder in adults: A systematic review and meta-analysis of long term outcome studies. *Clinical Psychology Review* 34(3): 249–255.

Nagai, M., H. Hikichi, K. Shiba, K. Kondo, I. Kawachi, and A.D. Jun. 2022. Long-term trend in the association between disaster damage and happiness before and after the Great East Japan Earthquake. *International Journal of Public Health* 67: Article 1604901.

NBS (National Bureau of Statistics of China). 2010. Statistical communiqué of the People's Republic of China on the 2009 national economic and social development. Beijing: National Bureau of Statistics of China. https://www.stats.gov.cn/english/NewsEvents/201002/t20100226_26295.html. Accessed 5 Mar 2024.

Norris, F.H., M.J. Friedman, P.J. Watson, C.M. Byrne, E. Diaz, and K. Kaniasty. 2002. 60,000 disaster victims speak: Part I—An empirical review of the empirical literature, 1981–2001. *Psychiatry* 65(3): 207–239.

Phifer, J.F. 1990. Psychological distress and somatic symptoms after natural disaster: Differential vulnerability among older adults. *Psychology and Aging* 5(3): 412–420.

Phifer, J.F., and F.H. Norris. 1989. Psychological symptoms in older adults following natural disaster: Nature, timing, duration, and course. *Journal of Gerontology* 44(6): S207–S217.

Prohaska, T.R., and K.E. Peters. 2019. Impact of natural disasters on health outcomes and cancer among older adults. *The Gerontologist* 59(Supplement 1): S50–S56.

Pruchno, R., M. Wilson-Genderson, A. Heid, and F. Cartwright. 2021. Trajectories of depressive symptoms experienced by older people: Effects of time, Hurricane Sandy, and the Great Recession. *The Journals of Gerontology: Series B, Psychological Sciences and Social Sciences* 76(5): 974–985.

Radloff, L.S. 1977. The CES-D scale: A self-report depression scale for research in the general population. *Applied Psychological Measurement* 1(3): 385–401.

Rafiey, H., Y.A. Momtaz, F. Alipour, H. Khankeh, S. Ahmadi, M. Sabzi Khoshnami, and S.A. Haron. 2016. Are older people more vulnerable to long-term impacts of disasters?. *Clinical Interventions in Aging* 11: 1791–1795.

Raker, E.J., S.R. Lowe, M.C. Arcaya, S.T. Johnson, J. Rhodes, and M.C. Waters. 2019. Twelve years later: The long-term mental health consequences of Hurricane Katrina. *Social Science & Medicine* 242: Article 112610.

Runkle, J.D., A. Brock-Martin, W. Karmaus, and E.R. Svendsen. 2012. Secondary surge capacity: A framework for understanding long-term access to primary care for medically vulnerable populations in disaster recovery. *American Journal of Public Health* 102(12): e24–e32.

Shi, P.J. 2019. *Disaster risk science*. Singapore: Springer.

Shi, P.J., X. Yang, W. Xu, and J.A. Wang. 2016. Mapping global mortality and affected population risks for multiple natural hazards. *International Journal of Disaster Risk Science* 7(1): 54–62.

Shin, S.H., and H. Ji. 2021. Health risks of natural hazards and resilience resources: Evidence from a U.S. nationwide longitudinal study. *Social Science & Medicine* 281: Article 114110.

Stroebe, K., B. Kanis, J. Richardson, F. Oldersma, J. Broer, F. Greven, and T. Postmes. 2021. Chronic disaster impact: The long-term psychological and physical health consequences of housing damage due to induced earthquakes. *BMJ Open* 11(5): e040710.

Strough, J.N., A.M. Parker, L. Ayer, V. Parks, and M.L. Finucane. 2024. Aging and emotional well-being after disasters: Vulnerability and resilience. *The Gerontologist* 64(3): Article gnad099.

Tang, B.H., X. Liu, Y. Liu, C. Xue, and L.L. Zhang. 2014. A meta-analysis of risk factors for depression in adults and children after natural disasters. *BMC Public Health* 14: Article 623.

Tierney, K. 2019. *Disasters: A sociological approach*. New York: John Wiley & Sons.

UNDRR (United Nations Office for Disaster Risk Reduction). 2022. *Global assessment report on disaster risk reduction 2022—Our world at risk: Transforming governance for a resilient future*. Geneva: UNDRR.

Xie, Y., and J.W. Hu. 2014. An introduction to the China Family Panel Studies (CFPS). *Chinese Sociological Review* 47(1): 3–29.

Xue, K.J., S.L. Guo, Y. Liu, S.Q. Liu, and D.D. Xu. 2021. Social networks, trust, and disaster-risk perceptions of rural residents in a multi-disaster environment: Evidence from Sichuan, China. *International Journal of Environmental Research and Public Health* 18(4): Article 2106.

Zhang, R., Y.Z. Zhang, and Z. Dai. 2022. Impact of natural disasters on mental health: A cross-sectional study based on the 2014 China Family Panel Survey. *International Journal of Environmental Research and Public Health* 19(5): Article 2511.

Zhong, S., M. Clark, X.Y. Hou, Y.L. Zang, and G. FitzGerald. 2014. Progress and challenges of disaster health management in China: A scoping review. *Global Health Action* 7: Article 24986.