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BASIC RESEARCH ARTICLE



Cumulative stressful events and mental health in young adults after 10 years of Wenchuan earthquake: the role of social support

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ABSTRACT

Background: After a natural disaster, stressful events often continue to accumulate, affecting individuals in a different manner than the original disaster ever occurred. However, few studies have examined these associations, the cumulative impacts of stressful events on mental health outcomes, and the role of social support. This study examined the prospective association between cumulative stressful events and mental health problems and the role of social support in young adults.

Methods: 695 participants provided available data on earthquake exposure, childhood maltreatment, other negative life events, and social support at baseline. Depressive symptoms and posttraumatic stress disorder were assessed at baseline and 10 years after the earthquake (T_{10y}). A cumulative stressful events index was used to evaluate the levels of cumulative stressful events. Linear regressions were used to explore the predictive effects.

Results: Of 695 participants, 41.3%, 28.5%, and 7.9% reported one, two, and three stressful events, respectively. The associations between cumulative stressful events and mental health problems at T_{10y} presented a dose-response pattern: those who experienced three events had the highest risk of mental health problems, followed by those who experienced two events and those who reported one event. Additionally, higher social support partially reduced the negative impact of cumulative stressful events on mental health.

Conclusions: Cumulative stressful events are associated with mental health problems 10 years later in young earthquake survivors. Social support could reduce the negative impact, but its protective role disappears when stressful events accumulate at the highest level. These findings highlight the importance of assessing the cumulative impacts of stressful events and social support available to young disaster survivors and intervening to prevent worse mental health outcomes.

Eventos estresantes acumulativos y salud mental en adultos jóvenes luego de 10 años del terremoto de Wenchuan: el papel del apoyo social

Antecedentes: Luego de un desastre natural, los eventos estresantes a menudo continúan acumulándose y afectan a las personas de una manera diferente de si el desastre original no hubiera ocurrido. Sin embargo, pocos estudios han examinado estas asociaciones, los impactos acumulativos de eventos estresantes sobre los resultados de salud mental y el papel del apoyo social. Este estudio examinó la asociación prospectiva entre eventos estresantes acumulativos y problemas de salud mental y el papel del apoyo social en adultos jóvenes.

Métodos: 695 participantes proporcionaron datos disponibles sobre exposición a terremotos, maltrato infantil, otros eventos negativos de la vida y apoyo social al inicio del estudio. Los síntomas depresivos y el trastorno de estrés postraumático se evaluaron al inicio y 10 años después del terremoto (T_{10y}). Se utilizó un índice de eventos estresantes acumulativos para evaluar los niveles de eventos estresantes acumulativos. Se utilizaron regresiones lineales para explorar los efectos predictivos.

Resultados: De 695 participantes, 41,3%, 28,5% y 7,9% reportaron uno, dos y tres eventos estresantes, respectivamente. Las asociaciones entre eventos estresantes acumulativos y problemas de salud mental en T_{10y} presentaron un patrón de dosis-respuesta: los que experimentaron tres eventos tenían el mayor riesgo de problemas de salud mental,

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Riesgos acumulados; salud mental; apoyo social; terremoto; cohorte longitudinal

关键词

累积风险; 心理健康; 社会支持; 地震; 纵向队列

HIGHLIGHTS

- The associations between cumulative stressful events and mental health problems 10 years presented a dose-response pattern.
- Social support could buffer the negative impacts, but its protective role disappears when stressful events accumulate at the highest level.
- It is critical to assess the cumulative impacts of stressful events and social support available to young disaster survivors to prevent worse mental health consequences.

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seguidos por los que experimentaron dos eventos y los que informaron un evento. Adicionalmente, mayor apoyo social redujo parcialmente el impacto negativo de los eventos estresantes acumulativos en la salud mental.

Conclusiones: Los eventos estresantes acumulativos se asocian con problemas de salud mental 10 años después en jóvenes sobrevivientes del terremoto. El apoyo social podría reducir el impacto negativo, pero su papel protector desaparece cuando los eventos estresantes se acumulan al máximo nivel. Estos hallazgos resaltan la importancia de evaluar los impactos acumulativos de los eventos estresantes y el apoyo social disponible para los jóvenes sobrevivientes de desastres e intervenir para prevenir peores resultados de salud mental.

汶川地震10年后年轻人的累积应激事件和心理健康：社会支持的作用

背景: 在自然灾害之后，应激性事件通常会继续积累，以与原始灾难不同的方式影响个人。但是，很少有研究考查应激事件对心理健康结果的累积影响以及社会支持作用的这些关联。本研究考查了年轻人中累积应激事件与心理健康问题与社会支持作用之间的前瞻性关联。

方法: 695名参与者提供了有关地震暴露、童年期虐待、其他负性生活事件和基线社会支持的可用数据。在基线和地震后10年(T10y)评估抑郁症状和创伤后应激障碍。使用累积应激事件指数评估累积应激事件的水平。使用线性回归考查预测效应。

结果: 在695名参与者中，分别有41.3%，28.5%和7.9%的参与者报告了一项、两项和三项应激事件。T10y的累积应激事件与心理健康问题之间的关联呈现出剂量反应模式：那些经历了三项事件的人出现了心理健康问题的风险最高，随后是那些经历了两项事件的人和报告了一项事件的人。此外，较高的社会支持部分减少了累积应激事件对心理健康的负面影响。

结论: 在年轻地震幸存者中，累积应激事件与十年后的心理健康问题有关。社会支持可能减少负面影响，但是当应激事件积累达到最高水平时，其保护作用就会消失。这些发现强调了评估年轻灾难幸存者可能遇到的应激事件和社会支持的累积影响的重要性，并进行干预以防止心理健康状况恶化。

1. Introduction

1.1. Mental health after natural disasters

Mental health problems are common in survivors of natural disasters, such as earthquakes, tsunamis, and wildfires (Cénat et al., 2020a). A meta-analysis of 27 studies around the globe has found that, after such disasters, rates of post-traumatic stress disorder (PTSD) and depression increased significantly among those affected (Beaglehole et al., 2018). In turn, mental health problems related to natural disaster exposure have been associated with further adverse consequences, such as suicidal behaviours (Chen et al., 2020; Jafari et al., 2020). It is therefore critical to identify protective and risk factors for mental health problems after disasters in order to develop effective intervention programmes.

1.2. Stressful events and mental health problems

Exposure to natural disasters has been suggested to increase the risk of developing mental health disorders (Fan et al., 2015; Zhou et al., 2016). In a 12-year survey among survivors of Hurricane Katrina, researchers found that exposure to hurricane-related traumatic events significantly predicted co-occurring post-traumatic stress symptoms (PTSS) (Raker et al., 2019). Another epidemiological survey following the Lushan earthquake showed that the prevalence of depressive

and trauma- and stressor-related disorders might have been influenced differently by the severity of the earthquake (Gao et al., 2021). Besides disaster exposure, psychosocial stressors have also been linked to mental health problems. Notably, childhood maltreatment is one of the most studied stressors. A meta-analysis has found that 12.7% of individuals reported sexual abuse, 22.6% physical abuse, 36.3% emotional abuse, 16.3% physical neglect, and 18.4% emotional neglect (Stoltenborgh et al., 2015). Maltreated individuals are at high risk for mental health problems (An et al., 2021; LeMoult et al., 2020). Furthermore, early adversity can enhance the responsiveness of later-on stressors based on the stress sensitisation model (Keyes et al., 2012). The risk of sustaining additional negative life events may increase after disasters, including those related to academic pressure and interpersonal difficulties (Tang et al., 2017), thereby increasing mental health risks (Catani et al., 2008). Jin and colleagues (2019) investigated 4402 adolescent survivors 3 years after the 2013 Ya'an earthquake. They found negative life events were significantly and positively related to PTSS after adjusting for gender and age (Jin et al., 2019).

Lifetime stressors are the sum of different stressors from early childhood through adulthood. It is critical to involve interpersonal stressful events experienced before and after natural disasters (Cénat et al., 2020b) to design more effective therapies and preventive interventions for traumatised individuals

(Suliman et al., 2009). When stressful events accumulate across the lifespan, they can lead to adverse health consequences (Evans et al., 2013; Scoglio et al., 2019; Su et al., 2022), and the more stressful the events experienced, the more possibility of developing mental health problems (Myers et al., 2015). For example, in a study of 6132 adolescents exposed to the Ya'an earthquake, researchers found that childhood maltreatment, negative life events, and earthquake exposure significantly contributed to psychotic-like experiences (Tang et al., 2021). Similar results were found in adolescents who had been exposed to severe and DSM-IV qualifying traumatic events. The researchers found that an increase in traumas was linearly associated with an increase in PTSD and depression (Suliman et al., 2009). However, these studies were limited by their cross-sectional designs, making it impossible to infer causal conclusions. In another, 10-year follow-up, community-based population study of 1351 participants, researchers found a significant association between the combined effects of cumulative stressful experiences (i.e. childhood maltreatment, parental bonding, and stressful life events) and future depression (Su et al., 2022). Overall, however, few studies on disasters have explored the prospective impacts of cumulative stressful events on future mental health problems.

1.3. The role of social support

Apart from exploring risk factors for mental health problems, identifying protective factors is equally important. Social support, a known protective factor, is negatively linked to PTSD and depression among individuals exposed to natural disasters (McGuire et al., 2018; Yuan et al., 2021). Two critical theories have been proposed to explain the effects of social support on mental health (Cohen & Wills, 1985). The main-effect model implies that social support has a direct effect on health irrespective of the number of stressful events and existing levels of support (Cohen & Wills, 1985). The buffering model, on the other hand, posits that stressful events will negatively affect health outcomes among individuals who have no or little social support; these negative impacts will therefore be reduced among individuals who have stronger social support systems (Cohen & McKay, 1984). One explanation of these findings is that high social support helps individuals gain purpose in life, self-esteem, and a sense of control or mastery of life. These positive traits help survivors build a more adaptive narrative of the traumatic event and thus alleviate psychological distress (Zhou et al., 2018). It is still unclear, however, whether the buffering effects of social support differ when stressful events accumulate. A cross-sectional survey with a random population sample in Sweden found that social support may

buffer the effect of being exposed to singular instances of violence or low-level polyvictimization (defined as experiencing more than one episode of violence) on one's sense of coherence, but the same is not true for high-level polyvictimization (Simmons & Swahnberg, 2021). Another study with 344 young adults in Cyprus aged 17–26 showed that perceived social support was more protective against depressive symptoms under moderate stress levels (Ioannou et al., 2019). However, similar research on the role of social support on the prospective association of cumulative stressful events with mental health problems among the disaster-exposed samples is limited.

1.4. The current study

Our objectives were to examine the predictive effects of cumulative stressful events in early life on mental health problems 10 years after the earthquake and to examine whether disparities in social support were associated with cumulative stressful events and mental health problems. Our first hypothesis was that stressful events could predict future mental health problems, with the association being most prominent for cumulative events. Our second hypothesis was that social support could distinguish the effect of cumulative stressful events on subsequent mental health problems, with higher social support being associated with better health conditions.

2. Methods

2.1. Participants and procedure

The 8.0-magnitude Wenchuan earthquake occurred on 12 May 2008 in Wenchuan County of Sichuan Province. The Wenchuan Earthquake Adolescent Health Cohort (WEAHC) was set up to document adolescent survivors' long-term mental health outcomes. Participants were recruited from two high schools in Dujiangyan City which is about 20 kilometres away from the epicentre and was one of the cities most affected by the earthquake. The reasons for selecting these two schools were: 1) they are public schools with a large number of enrolments, 2) students come from a variety of socio-economic backgrounds, which could be considered representative of the high school student population in the district, and 3) the school principals were willing to participate in the study. We recruited 7th ($n = 216$) and 10th graders ($n = 1357$) for this longitudinal study as they could be followed up for 2 years prior to their graduation. Participants were initially assessed at 6 months post-earthquake, and four follow-up assessments were carried out at 6-month intervals. Detailed sampling and assessments of this original cohort could be found elsewhere (Fan et al., 2016). This current study

extended the WEAHC and was conducted 10 years after the earthquake (i.e. in 2018). We aimed to understand adulthood outcomes associated with adolescent earthquake exposure. At this 10-year follow-up, we only surveyed 10th graders due to limited resources. To find those participants, local teachers directed researchers to willing participants. These participants completed questionnaires via an online platform that was specifically developed by our team for this project. Ultimately, 799 participants responded to our online survey (the response rate was 58.9%). The present study included 695 samples which provided available data on our interested variables at 6 months (T_{6m}) and 10 years (T_{10y}).

Approval for our study was granted by the Human Research Ethics Committee of South China Normal University. At T_{6m} , informed written consent was obtained from participants and their parents. Students completed self-administered paper-and-pencil questionnaires in the classroom during school days under the instructions of trained interviewers. At T_{10y} , informed written consent was obtained from participants. Those participants completed an online survey. Participants were told that they could withdraw from the study at any time.

2.2. Measures

Cumulative stressful events refer to earthquake exposure, childhood maltreatment, and other negative life events at baseline. Detailed descriptions of each type of event are as follows.

2.3. Earthquake exposure

Two items of earthquake exposure were used: (1) casualties of family members (1 = death of family members, 2 = disappearance of family members, 3 = severe injury of family members, 4 = few injuries of family members, 5 = none of the above) and (2) witness of tragic scenes (1 = directly viewing many tragic scenes, 2 = directly viewing some tragic scenes, 3 = hearing many from others, 4 = hearing some from others, 5 = none of the above). To define a dichotomous variable of each item, we recorded each item into two categories (0 = No exposure and 1 = Exposure). Specifically, for ‘casualties of family members’, the original categories 1, 2, and 3 were grouped into a new category 1 (Yes exposure to casualties of family members), and the remains were identified as category 0 (No exposure to casualties of family members). For ‘witness of tragic scenes’, the original categories 1 and 2 were classified as category 1 (Yes exposure to witness of tragic scenes), and the remains were into category 0 (No exposure to witness of tragic scenes).

A dichotomous variable of earthquake exposure was classified: experienced earthquake exposure (i.e. exposure to either or both events) or no experienced earthquake exposure (i.e. exposure to neither event).

2.4. Childhood maltreatment

The Chinese version of the Childhood Trauma Questionnaire Short Form (CTQ-SF) is a 28-item screening inventory. It evaluates self-reported experiences of childhood maltreatment before age 16 (Zhao et al., 2005). There are five subscales, including emotional abuse, physical abuse, sexual abuse, emotional neglect, and physical neglect. Participants rated each item on a 5-point scale ranging from 1 = never to 5 = always. The score for each subscale ranges from 5 to 25. Moderate to severe cutoff scores are emotional abuse (≥ 13), physical abuse (≥ 10), sexual abuse (≥ 8), emotional neglect (≥ 15), and physical neglect (≥ 10). In the present study, Cronbach’s alphas of the scale were 0.74 for emotional abuse, 0.86 for physical abuse, 0.89 for sexual abuse, 0.90 for emotional neglect, and 0.58 for physical neglect.

A dichotomous variable of any childhood maltreatment was classified based on previous work (Chen et al., 2021): participants either experienced childhood maltreatment (i.e. participants reported at least moderate to severe cutoff scores in one of the subscales of CTQ) or did not experience childhood maltreatment (i.e. no report of any maltreatment).

2.5. Negative life events at baseline

The Adolescent Self-Rating Life Events Checklist (ASLEC) (Liu et al., 1997) was used to evaluate the severity of negative life events at baseline. It includes 26 items measuring six domains (e.g. academic pressure, interpersonal conflicts, personal loss, being punished, physical health problems, and others). Each item was rated on a 5-point scale ranging from 1 (not at all) to 5 (extremely severe). All items were summed to create a total score, with higher scores representing more severe negative life events. The ASLEC has shown good reliability and validity among Chinese adolescent samples (Liu et al., 1997). In the present study, Cronbach’s alpha of the scale was 0.88 at baseline.

A dichotomous variable of negative life events at baseline was classified based on previous work (Fan et al., 2015; Wang et al., 2022): exposure to negative life events (i.e. the score was equal and above 73rd percentile) or no exposure to negative life events.

2.6. Cumulative stress index

The reasons for constructing the cumulative stress index by dichotomising each risk factor exposure

(0 = no risk; 1 = risk) and then summing the dichotomous scores are twofold. On the one hand, this cumulative risk factor assessment was in line with previous theoretical models. For example, the allostasis model of chronic stress assumes that allostatic load costs may lead to cumulative damage when stress is multiple (McEwen, 1998). On the other hand, this metric has several strengths as Evans et al. (2013) discussed. For example, risk factors are unweighted in this cumulative risk factor index, thus making no assumptions about the relative strength of different risk factors. The quantity seems more important than the quality of risk factor exposures. Moreover, this index is parsimonious and is also insensitive to the degree of covariation among risk factors.

Empirical studies (e.g. Brownlow et al., 2018; Tung et al., 2016) also constructed a cumulative stressful events index by creating a composite metric wherein a set of dichotomous risk factor exposure were summed together. Therefore, we constructed a cumulative stressful events index as follows: No reports of any of the above events were classified into group '0'. Reports of any single event were classified into group '1'. Reports of any two events were classified into group '2'. Reports of all three events were classified into group '3'. Higher sums indicate a greater number of stressful events.

3. Mental health problems at T_{10y} (PTSD symptoms & Depression)

3.1. PTSD symptoms at T_{10y}

The Posttraumatic Stress Disorder Checklist (PCL-5) was used to evaluate PTSD symptoms related to the earthquake at T_{10y}. It is a 20-item scale rated on a 5-point scale ranging from 0 (not at all) to 4 (extremely). All items were summed to generate a score, with a higher score representing more severe PTSD symptoms. This scale has excellent psychometric properties in the Chinese sample (Wang et al., 2018). In the current study, Cronbach's alpha was 0.91.

3.2. Depression at T_{10y}

The Patient Health Questionnaire 9-item depression scale (PHQ-9) was used to measure depression at T_{10y} (Kroenke et al., 2001). The PHQ-9 is rated on a 4-point scale ranging from 0 (not at all) to 3 (nearly all days). All items were summed to obtain a total score of PHQ-9, with a higher total score indicating more severe depressive symptoms. The scale has good psychometric properties in the Chinese sample (Wang et al., 2014). In this study, Cronbach's alpha was 0.88.

3.3. Social support

The Chinese version of the Social Support Rating Scale (SSRS) was used to assess social support (Xiao, 1994). It consists of 10 items covering three aspects: objective support, subjective support, and utilisation of social support. Items were summed to obtain a total social support score, with a higher score representing a greater level of social support. This scale has been used among Chinese students sample (Shi et al., 2016). In the current study, Cronbach's alpha was 0.74 at T_{6m}.

4. Study covariates

4.1. Demographic characteristics

Age at baseline, sex, education (T_{10y}), marriage (T_{10y}), and income (T_{10y}) were collected.

4.2. Negative life events at T_{10y}

10 items were used to measure negative life events at T_{10y}. These 10 items were devised based on The Adolescent Self-Rating Life Events Checklist (ASLEC) (Liu et al., 1997). Items of ASLEC related to adolescents (e.g. academic pressure) were deleted. We added items for negative events related to adulthood (e.g. the death of a close family member, relative, or subject of severe injury or illness). Two choices were provided: 0 (not happened/didn't know) and 1 (happened). In the current study, Cronbach's alpha was 0.68 at T_{10y}.

4.3. PTSD symptoms at T_{6m}

The Posttraumatic Stress Disorder Self-Rating Scale (PTSD-SS) was used to assess adolescents' PTSD symptoms (Liu et al., 1998) at T_{6m}. It is 24-item, and each item is rated from 1 = none to 5 = very severe. All items were summed, with a higher score indicating more severe PTSD symptoms. Psychometric properties of PTSD have been described in the Chinese population (Liu et al., 1998). In the current study, Cronbach's alpha was 0.94.

4.4. Depression at T_{6m}

The Depression Self-Rating Scale for Children (DSRSC) was used to assess depressive symptoms at T_{6m} (Su et al., 2003). The DSRSC is an 18-item scale rating from 0 (never) to 2 (mostly). All items were summed to obtain the total score. This scale has been used to measure adolescents' depression post-earthquake (Zhou et al., 2016). In this study, Cronbach's alpha of DSRSC was 0.79.

4.5. Statistical analysis

695 participants were included in the final analyses. We conducted the comparison of baseline demographics (age and sex) between those included ($N = 695$) and those not ($N = 662$). The results showed that there were no significant differences in age between the two groups ($t = -0.147$, $p = .883$). As for sex differences, males were more likely to drop out ($\chi^2 = 11.40$, $p = .001$). We used the Little's Missing Completely at Random (MCAR) test to analyse the missing data of continuous variables (numbers of missing data ranging from 1 to 10). The results showed that missing data were at random $\chi^2(30) = 37.41$, $p = .17$. An expectation-maximization (EM) algorithm was used to impute those missing data as previous work did (Fan et al., 2015; Shi et al., 2016; Zhou et al., 2016).

To test the predictive effects of cumulative stressful events on mental health problems, linear regressions were used (Evans et al., 2013; Overstreet et al., 2016). PTSD and depression were transformed into z scores before entering the regression models because different questionnaires were used at different age stages. Two models were tested (crude and adjusted models). Only independent (numbers of stressful events, i.e. 0, 1, 2, and 3) and dependent (PTSD and depression) variables were included in crude models. In adjusted models, we entered demographic variables (sex, age at baseline, education at T_{10y} , marriage at T_{10y} , and income at T_{10y}), negative life events at T_{10y} , and the specific mental health problem (depression at T_{6m} or PTSD at T_{6m}) as covariates. Then, we performed both stratified analyses varied by low and high levels of social support and effect modification analyses by adding an interaction term of the cumulative risk factor index and social support

in the model to examine the effects of social support. Some previous work also conducted both interaction testing and stratified analyses to test moderation (e.g. Srikanthan et al., 2009). A high level of social support was defined as equal to and above the 73rd percentile (Fan et al., 2015; Wang et al., 2022). The remaining was a low level of social support.

4.6. Sensitivity analysis

We conducted two sensitivity analyses to create cumulative stressful events and test the predictive effects on future mental health. The first approach was to separately calculate stressful events (earthquake exposure, childhood maltreatment, and negative life events) into a standardised z -score (Vinkers et al., 2014). A z -score ≥ 1 was considered risky and coded as 1, and a z -score < 1 was considered risk-free and coded as 0 (Ma et al., 2022). Therefore, each event was recorded as 1 (risk) or 0 (risk-free). The same steps were conducted when we calculated the cumulative risk index into 0, 1, 2, and 3. Higher scores on the cumulative stress index represented more cumulative stress events experienced. Furthermore, we used linear regressions to examine the predictive effects of different levels of stressful events on mental health problems.

The second approach was to delineate different profiles of stressful events. Latent profile analysis (LPA) was used to explore the clustering of events. It is a robust statistical technique using continuous variables to identify subgroups of homogeneous latent classes (Achterhof et al., 2019). Previous work also employed this approach to analyse cumulative lifetime stressors (Su et al., 2022). The analysis started with the most parsimonious one-class model, then extended to include additional models. Several indicators are used to decide on the best-fitting model: lowest information criteria (Akaike's information criterion [AIC], the Bayesian information criterion [BIC], the sample size-adjusted Bayesian information criterion [SSBIC]), a high entropy (close to 1), statistically significant p values for both the Lo-Mendell-Rubin (LRT), bootstrap likelihood ratio test (BLRT), and proportions of participants in each class (at least 5%) (Nylund et al., 2007). After deciding on the model, we also used linear regressions to test the predictive effect.

Table 1. Sample characteristics and stressful events ($N = 695$).

	<i>N</i> (%)
Age (T_{6m}), mean (<i>SD</i>)	15.44 (0.65)
Sex, female	413 (59.4)
Education (T_{10y})	
High school or less	212 (30.5)
College and above	483 (69.5)
Marriage (T_{10y})	
Unmarried	472 (67.9)
Married	223 (32.1)
Personal income (T_{10y}) ^a , RMB	
<30,000	131 (18.9)
30,000 - 60,000	239 (34.4)
60,000 - 120,000	261 (37.6)
>120,000	63 (9.1)
Any earthquake exposure, Yes	435 (62.6)
Any childhood maltreatment, Yes	211 (30.4)
Any negative life events at T_{6m} , Yes	202 (29.1)
Numbers of stressful events	
Number = 0	155 (22.3)
Number = 1	287 (41.3)
Number = 2	198 (28.5)
Number = 3	55 (7.9)

Note: ^a $N = 694$ because of missing data. $T_{6m} = 6$ months after the earthquake. $T_{10y} = 10$ years after the earthquake.

Table 2. Correlations among main study variables.

Variables	1	2	3	4	5
1. Earthquake exposure	-				
2. Childhood maltreatment	0.09*	-			
3. Negative life events T_{6m}	0.14**	0.17**	-		
4. Depression at T_{10y}	0.09*	0.33**	0.21**	-	
5. PTSD at T_{10y}	0.19**	0.33**	0.18**	0.59**	-

Note: $T_{6m} = 6$ months after the earthquake. $T_{10y} = 10$ years after the earthquake. * $p < .05$; ** $p < .01$.

5. Results

5.1. Sample characteristics and correlations between main variables

Table 1 shows a detailed description of the sample. The average age at baseline was 15.44 ($SD = 0.65$) and 59.4% were females. 22.3% of participants did not experience any negative life events measured in the study (i.e. earthquake exposure, childhood maltreatment, or negative life events). 41.3% of participants reported one of the events. 36.4% of survivors have experienced at least two or three events. Table 2 shows the correlations between stressful events and future mental health problems. Significant positive associations between stressful events and mental health problems (PTSD and depression at T_{10y}) were observed.

5.2. Cumulative stressors in associations with mental health problems

Linear regressions were used to test the unadjusted and adjusted associations between stressors and mental health problems at T_{10y} (Table 3). The associations between numbers of stressful events and depression showed a dose-response pattern even when controlling for demographic factors, negative life events at T_{10y} , and baseline mental health conditions. In other words, those with the highest stress levels had the highest risk of future depression and PTSD. Specifically, those who experienced three events had the highest risk of suffering depression ($\beta = 0.15$, 95% CI [0.27, 0.87]), followed by those who experienced two events ($\beta = 0.14$, 95% CI [0.11, 0.51]), and by those who reported one event ($\beta = 0.136$, 95% CI [0.10, 0.45]). Similar patterns were found when PTSD was an outcome: those who experienced three events had the highest risk of experiencing PTSD ($\beta = 0.16$, 95% CI [0.30, 0.91]), followed by those who experienced two events ($\beta = 0.12$, 95% CI [0.06, 0.46]), and by those who reported one event ($\beta = 0.09$, 95% CI [0.002, 0.36]). Taken together, the growth rate of PTSD and depression increased as stressful events cumulated.

5.3. The role of social support in the association between stressful events and mental health problems

In the stratified analysis of social support as shown in Table 4a-b, survivors with low social support were more likely to report future depression and PTSD. The associations were consistent for one, two, and three cumulative events. When the stressful events accumulate at their maximum level (i.e. number = 3), higher social support is insufficient to protect

survivors from suffering from PTSD and depression. In addition, we tested for social support differences in the association between cumulative risk and future mental health by adding social support interaction terms to the model. The interaction was significant when the outcome was depression ($\beta = 0.165$, 95% CI [0.005, 0.028]) but not PTSD ($\beta = 0.026$, 95% CI [-0.009, 0.014]).

5.4. Sensitivity analysis

In the first sensitivity analysis, we transformed stress events into z -scores. The linear regressions showed that individuals reporting more stressors were more likely to experience depression and PTSD in adjusted models (details can be found in S2). Therefore, this sensitivity analysis supports our above findings.

Secondly, we employed LPA to distinguish different profiles of stressful events. One to five models were tested. The fit indices are shown in S1. The AIC and BIC values decreased from one to five. Models 2 and 3 had the same entropy. However, model 3 had a small group (4%). Therefore, the 2-class model was selected because it best fits the data. Group 1 (*low-stress group*, $n = 616$, 88.6%) presented participants who experienced low stressful events. Group 2 (*high-stress group*, $n = 79$, 11.4%) showed participants who suffered high stressful events. We further used linear regressions to explore the predictive effects of different groups on mental health at T_{10y} . We found in the adjusted model that individuals with high-stress were more likely to suffer from depression ($\beta = 0.14$, 95%CI [0.22, 0.66]) and PTSD ($\beta = 0.15$, 95%CI [0.26, 0.70]) than those with low-stress.

6. Discussion

This study aimed to examine the associations between cumulative stressful events (i.e. childhood maltreatment, earthquake exposure, and negative life events post-earthquake) and mental health consequences 10 years after the earthquake. We further evaluated the protective effect of social support on these associations. Results showed that an increasing number of stressful events was associated with a higher probability of mental health problems later in life, even when controlling for previous mental health conditions. Notably, this association has a dose-dependent relationship: those who reported three stressful events were at higher risk of developing mental health problems than those who reported two or one event (s). In addition, higher social support was generally associated with improved outcomes. Merely having a supportive social environment, however, may be insufficient when stressful events accumulate to a high level (i.e. three events in this study).

Table 3. Numbers of stressful events predict depression and PTSD 10 years after the earthquake using linear regressions.

		Depression at T _{10y}			PTSD at T _{10y}		
		B	β	95% CI	B	β	95% CI
Crude model	Number = 0		Ref.			Ref.	
	Number = 1	0.35	0.17	(0.16, 0.54)***	0.27	0.13	(0.08, 0.46)**
	Number = 2	0.51	0.23	(0.30, 0.71)***	0.52	0.24	(0.32, 0.72)***
	Number = 3	1.06	0.29	(0.76, 1.36)***	1.20	0.32	(0.90, 1.49)***
Adjusted model ^b	Number = 0		Ref.			Ref.	
	Number = 1	0.28	0.136	(0.10, 0.45)**	0.18	0.09	(0.002, 0.36)*
	Number = 2	0.31	0.14	(0.11, 0.51)**	0.26	0.12	(0.06, 0.46)**
	Number = 3	0.57	0.15	(0.27, 0.87)***	0.60	0.16	(0.30, 0.91)***

Note: ^bAdjusted for the specific mental health problem (depression at T_{6m} or PTSD at T_{6m}), age, sex, education (T_{10y}), marriage (T_{10y}), income (T_{10y}), and negative life events (T_{10y}). ^bN = 694, because of missing data on income.

T_{6m} = 6 months after the earthquake. T_{10y} = 10 years after the earthquake. * $p < .05$; ** $p < .01$; *** $p < .001$.

Previous studies have reported that stressful events increased the risk of developing mental health problems (Suliman et al., 2009; Tang et al., 2021). However, these studies were mostly cross-sectional in nature. Our study, which uses a 10-year follow-up, earthquake-exposed sample supports the notion that disaster research should longitudinally explore the cumulative effect of interpersonal stressful events before and after the disaster on the development of long-term, trauma-related mental health problems (Cénat et al., 2020b). We found a dose-response association between cumulative stressful events and mental health problems: those with the highest stress levels had the highest risk of future mental health problems. The theory of allostatic load may explain this finding. Allostatic load is a process by which the body regulates the physiological responses (e.g. hormones of the HPA axis, catecholamines, the parasympathetic nervous system, and pro-and anti-inflammatory cytokines) to accommodate changing environmental demand (Sterling & Eyer, 1988). Allostatic load costs may lead to cumulative damage when stress is intense (McEwen, 1998). This multi-systemic

‘wear and tear’ may lead to psychiatric symptoms (Juster et al., 2010). Future studies could therefore explore allostatic load as a mechanism linking cumulative events and mental illness.

The present result in the stratified analyses showed that social support can facilitate healthy adaptation processes for earthquake survivors. This is consistent with empirical studies showing that social support could protect survivors from mental health problems (Cénat et al., 2020b). Despite their different hypotheses, two prominent theories of social support (the main-effect model and the buffering model) also support the protective effect of a strong social environment (Cohen & Wills, 1985). Our current finding extends these theories by showing that this protective effect may be insufficient when stressful events accumulate at the highest level. This result echoes a nationally representative study of adolescents showing that social support alone is insufficient for youth with overwhelming amounts of adverse experiences (Pan et al., 2020). Indeed, another survey of young adults found that social support protects against depression only under moderate stress (Ioannou et al., 2019).

Table 4. (a) Numbers of stressful events predict depression 10 years after the earthquake using linear regressions, stratified by social support (b) Numbers of stressful events predict PTSD 10 years after the earthquake using linear regressions, stratified by social support.

		Depression at T _{10y}					
		Low SS (n = 506)			High SS (n = 188)		
		B	β	95% CI	B	β	95% CI
Adjusted model ^b	Number = 0		Ref.			Ref.	
	Number = 1				0.28	0.15	(−0.04, 0.60)
	Number = 2	0.26	0.127	(0.04, 0.48)*	0.28	0.13	(−0.08, 0.64)
	Number = 3	0.33	0.147	(0.09, 0.56)**	0.98	0.23	(0.36, 1.60)**
		0.47	0.133	(0.12, 0.81)**			

		PTSD at T _{10y}					
		Low SS (n = 506)			High SS (n = 188)		
		B	β	95% CI	B	β	95% CI
Adjusted model ^b	Number = 0		Ref.			Ref.	
	Number = 1	0.19	0.09	(−0.03, 0.41) $p = .084$	0.15	0.08	(−0.17, 0.47)
	Number = 2	0.27	0.12	(0.03, 0.51)*	0.23	0.11	(−0.14, 0.60)
	Number = 3	0.43	0.123	(0.08, 0.78)*	1.28	0.29	(0.60, 1.96)***

Note: ^bAdjusted for PTSD at T_{6m}, age, sex, education (T_{10y}), marriage (T_{10y}), income (T_{10y}), and negative life events (T_{10y}). ^bN = 694, because of missing data on income.

T_{6m} = 6 months after the earthquake. T_{10y} = 10 years after the earthquake. * $p < .05$; *** $p < .001$.

Additionally, it is worth mentioning that the buffering effect of social support was more apparent in the reduction of depression when conducting the interaction analyses. The potential reason might be that PTSD was more associated with trauma exposure itself, while depression may be largely dependent on subsequent stressors and social support (Adams et al., 2019). Therefore, practitioners should explore other protective factors for earthquake survivors. For example, a meta-analysis has indicated that greater use of positive coping is associated with fewer PTSS (Gordon-Hollingsworth et al., 2018).

7. Implications

By highlighting the impacts of cumulative stressful events on mental health problems among an earthquake-survivor sample, we found the growth rate of PTSD and depression increased as stressful events cumulated. This finding has further implications for treatments. On the one hand, assessing stressful events before and after a disaster is necessary because these events could together affect survivors' mental health (Ni et al., 2022). Merely dealing with a single event may be insufficient and unlikely to have important preventive effects for those exposed to multiple events (Green et al., 2010). Practically, clinical practitioners providing support to disaster-exposed survivors are strongly suggested to ask clients not only about disaster exposure but also about other events, such as histories of childhood adversity and negative life events after the disaster. Such work could provide valuable insights into survivors' experiences, which may promote better mental health interventions. On the other hand, clinical research and practice may need to determine whether those exposed to multiple stressors require tailored or additional treatments. Meanwhile, more work is needed to examine whether persons with more traumatic events are less responsive to treatments (Karam et al., 2014).

Social support can buffer the effects of stressful events, shedding light on one potential direction for interventions. Nurturing a supportive family and community is necessary to help these survivors establish a supportive social network by enriching existing relationships, promoting new networks, and improving interpersonal skills (Lowe & Willis, 2015). However, a supportive environment alone might not be sufficient for survivors with overwhelming stressful events. Therefore, professional and comprehensive interventional programmes are needed to provide additional help to those individuals.

8. Limitations

Our study has several strengths, including a 10-year follow-up design with an earthquake-exposed sample

and an exploration of the role of social support in the longitudinal influence of cumulative risk on future mental health. However, the following limitations should be acknowledged when interpreting our results. Firstly, all measures were self-reported, which may lead to reporting bias. Secondly, the response rate is relatively low, although we made all efforts to contact participants. In addition, males were more likely to drop out in the present study, which should be cautious when interpreting our findings. Thirdly, although we found a protective effect of social support, more detailed information (e.g. the quality and quantity of support) might provide a more comprehensive social picture. Fourthly, the generalizability of the present findings is restricted by age and its earthquake-exposed nature. Fifthly, the mechanism between cumulative risks and mental health problems should be further explored. Lastly, childhood maltreatment was measured in a retrospective way. Practitioners are suggested to seek out information from different sources whenever feasible (Shaffer et al., 2008).

9. Conclusion

This study showed a longitudinal relationship between cumulative stressful events and mental health problems among an earthquake-exposed sample. Specifically, exposure to a greater number of stressful events was found to increase the likelihood of future mental health problems. The findings also suggest that high social support may relieve the negative impacts of stressful events on mental health problems. However, these protective effects may be insufficient when stressful events accumulate to the highest level. We therefore call for more attention to survivors of disasters who suffer from cumulative stressful events and the prioritisation of social supports and mental health interventions for those in need.

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Data availability statement

Research data are not shared, as the data belongs to a longitudinal project, which most data have not been published.

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Appendix

S1 Fit indices for one- to five- class models for cumulative life events

Fit indices	1-class	2-class	3-class	4-class	5-class
AIC	13688.92	13404.46	13256.04	13148.20	13103.23
BIC	13716.19	13449.90	13319.66	13229.99	13203.19
SSBIC	13697.14	13418.14	13275.21	13172.84	13133.34
Entropy	-	0.93	0.93	0.92	0.90
LRT <i>p</i> value	-	<.001	<.001	.02	.05
BLRT <i>p</i> value	-	<.001	<.001	<.001	<.001

Note: Bold indicates the final selected class.

S2 Numbers of stressful events predict depression and PTSD 10 years after the earthquake

	Depression at T _{10y}			PTSD at T _{10y}		
	B	β	95% CI	B	β	95% CI
Sensitivity analysis 1: Stressful events as a standardised z-score						
Number = 0			Ref.			Ref.
Number = 1	0.21	0.09	(0.05, 0.36)*	0.17	0.08	(0.01, 0.33)*
Number = 2 + 3 ^a	0.31	0.08	(0.02, 0.60)*	0.47	0.12	(0.18, 0.77)**
Sensitivity analysis 2: Stressful events identified by LPA						
Low-stress group						
(n = 616, 88.6%)			Ref.			Ref.
High-stress group	0.44	0.14	(0.22, 0.66)***	0.48	0.15	(0.26, 0.70)***
(n = 79, 11.4%)						

Note. ^a we combined stressful events '2 and 3' because of a limited number of 3. N = 694 because of missing data on income. Both models were adjusted for the specific mental health problem (depression at T_{6m} or PTSD at T_{6m}), age, sex, education (T_{10y}), marriage (T_{10y}), income (T_{10y}), and negative life events (T_{10y}).

T_{6m} = 6 months after the earthquake. T_{10y} = 10 years after the earthquake. **p* < .05; ***p* < .01; ****p* < .001.