



Research paper

Posttraumatic stress disorder symptoms in mothers and adolescents after the Wenchuan earthquake: A cross-sectional and longitudinal network analysis

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ABSTRACT

Objective: This study used network analysis to investigate the cross-sectional and longitudinal network between PTSD symptoms within mother-adolescent dyads at 12 and 18 months after the 2008 Wenchuan earthquake. **Methods:** The sample was from the Wenchuan Earthquake Adolescent Health Cohort. 399 mother-adolescent dyads completed the Posttraumatic Stress Disorder Self-Rating Scale at 12 and 18 months after the earthquake. We assessed central symptoms (those with the most significant influence on other symptoms) and bridge symptoms (symptoms connecting different communities) in contemporary networks (i.e., cross-sectional networks). Subsequently, cross-lagged panel network analyses (CLPN) were performed to estimate longitudinal relationships among symptoms between dyads.

Results: In the contemporary networks, symptoms such as “intrusive thoughts” of both dyads and “flashbacks” of adolescents were central, indicating that they are crucial in maintaining the network of PTSD symptoms. Additional symptoms such as maternal “difficulty in concentration” and dyads’ “pessimism and disappointment” should also be considered because of their central roles. Moreover, the temporary network did not directly replicate the contemporary networks, with adolescents’ “nightmares” at 12 months having a high influence on other PTSD symptoms at 18 months.

Limitations: Self-reported tools other than clinical diagnoses were used to collect data.

Conclusions: These symptom-level associations at cross-sectional and longitudinal networks extend our understanding of PTSD symptoms among mother-adolescent dyads by pointing to specific key symptoms of PTSD that may drive the co-occurrence of PTSD among dyads. Recognizing these symptoms is imperative for the development of targeted interventions and treatments aimed at addressing comorbid PTSD in mother-adolescent dyads.

1. Introduction

Survivors of natural disasters often grapple with mental health sequelae, including posttraumatic stress disorder (PTSD) symptoms, a prevalent mental health concern (Hosseinnajad et al., 2022). A meta-analysis has shown that the pooled prevalence of PTSD among children and adolescent survivors after earthquakes and floods was 19.2%, 30.0%, 24.4%, and 20.4%, in the first, second, third, and fourth six-

month intervals after the disaster, respectively (Rezayat et al., 2020). Among female adult survivors of the Wenchuan earthquake, 9.5% of them had chronic PTSD, and 7.6% had delayed-onset PTSD (Chen et al., 2020). PTSD is linked to a range of adverse outcomes, including an increased risk of suicide (Guo et al., 2017). Therefore, addressing PTSD in the context of disaster recovery is of paramount importance.

The mutual impacts of adolescent and parental PTSD following a disaster have been explored in the literature. On one hand, the presence

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of parental PTSD, particularly in mothers, can impact their children for several reasons. Firstly, women experience a higher prevalence of PTSD (Hosseinejad *et al.*, 2022) and typically engage in more frequent interactions with their children (Silverstein *et al.*, 2022). This proximity offers mothers numerous opportunities to exemplify and reinforce either adaptive or maladaptive coping strategies in their offspring (Silverstein *et al.*, 2022). Secondly, the transmission of risk for child PTSD from mothers with PTSD can be partially attributed to epigenetic mechanisms (Yehuda and Bierer, 2009). Empirical research has indeed found a positive association between maternal and offspring PTSD. For instance, a decade-long longitudinal study after the earthquake demonstrated that chronic maternal PTSD was associated with subsequent adolescent PTSD (Chen *et al.*, 2020). A similar finding was observed in another prospective investigation (Shi *et al.*, 2018). However, some studies have reported found no significant relationship (Self-Brown *et al.*, 2006). For instance, maternal PTSD did not predict a youth's PTSD six months after a road traffic accident (Kolaitis *et al.*, 2011). On the other hand, the severity of a child's PTSD symptoms can also impact the mother (Boyer *et al.*, 2000). A longitudinal study found that adolescent PTSD predicted future maternal PTSD (Shi *et al.*, 2018). However, other research has shown that a child's PTSD symptoms do not predict maternal symptoms (Landolt *et al.*, 2012). A study of parent-child dyads in a rural Indonesian community ravaged by a severe earthquake found that maternal PTSD symptoms were not influenced by the child's symptoms (Juth *et al.*, 2015). These disparate findings might be attributed to the studies' reliance on linear relationships between variables, potentially overlooking the intricate interplay of symptoms (Ma *et al.*, 2022).

Network modeling offers a complementary approach that emphasizes the importance of understanding associations at the level of individual symptoms (Borsboom and Cramer, 2013). From a network theory perspective, mental health disorders arise from the complex interplay among symptoms (Borsboom, 2008). Network analysis provides both a visual and a quantitative depiction of symptom interconnections (Borsboom and Cramer, 2013). This approach is capable of pinpointing central symptoms (i.e., those that exert the greatest influence on other symptoms within the network). Moreover, it can identify bridge symptoms connecting different communities (e.g., those between mothers and adolescents) (Kaiser *et al.*, 2021). These bridge symptoms involve a symptom in one disorder activating symptoms in another, thereby creating a feedback loop that may contribute to the onset and maintenance of co-occurring disorders (Cramer *et al.*, 2010). Investigating both central and bridge symptoms holds promise for the development of targeted interventions. The rationale is that by addressing central symptoms, the activation of connected symptoms may be reduced, thereby facilitating recovery from PTSD (Borsboom and Cramer, 2013). This strategy aligns with research suggesting that targeting specific symptoms can support the overall recovery process from PTSD (Eli *et al.*, 2021).

Network analysis has been used to explore the structure of PTSD symptoms in both adolescents (An *et al.*, 2022; Russell *et al.*, 2017) and adults (Gay *et al.*, 2020; Yang *et al.*, 2022) after disasters. A meta-analysis incorporating 52 different samples found that central symptoms can differ across studies (Isvoranu *et al.*, 2021). In addition, symptom networks are not static (Robinaugh *et al.*, 2020). Examining the structure and stability of symptoms helps clarify the mechanisms behind the perseverance and resilience of co-occurring symptoms (Bringmann *et al.*, 2015). Two longitudinal studies examining the aftermath of earthquakes in China have highlighted the variability in central symptoms at different stages (Ge *et al.*, 2019; Liang *et al.*, 2020). Ge *et al.* (2019) assessed youth survivors of the Lushan earthquake and found the overall network connectivity was significantly stronger at three months than at two weeks post-disaster and significantly stronger at six months than at the two weeks. Liang *et al.* (2020) assessed children after the Wenchuan earthquake and found that flashbacks consistently maintained a high centrality across all time points, while other symptoms with a high centrality varied across time points. Although these

longitudinal investigations are valuable, they have not delved into the dynamics of PTSD symptoms as an interacting network within dyads. Very few studies examined PTSD at the symptom level in children and their parents (Cervin *et al.*, 2021). Cervin and colleagues found a network that showed the associations between major symptom clusters of child PTSD and caregivers (Cervin *et al.*, 2021). Nonetheless, the study did not investigate the varied symptoms of PTSD in caregivers and was constrained by its cross-sectional design, precluding an understanding of the evolution of symptom networks within dyads.

Several studies have indicated the importance of concurrently examining both cross-sectional (i.e., contemporary) and longitudinal (i.e., temporal) networks to achieve a comprehensive grasp of symptomatology (Qi *et al.*, 2023; Zainal and Newman, 2023). In light of this, our current study aimed to evaluate the contemporary networks of PTSD symptoms within mother-adolescent dyads, to identify central and bridge symptoms within these networks. Additionally, we employed cross-lagged panel network (CLPN) models with two-wave longitudinal data to explore the temporal networks. The CLPN can identify symptoms with a high out-expected influence (i.e., symptoms that are most predictive of other symptoms at the subsequent time point) and a high in-expected influence (i.e., symptoms that are most predicted by other symptoms at the prior time point) (Funkhouser *et al.*, 2021). This approach provides robust inferences at the symptom level, thereby enhancing our understanding of the longitudinal dynamics of PTSD symptoms among mother-adolescent dyads.

Inspired by the network approach, the aims of the current study are twofold. One is to identify central and bridge symptoms in the contemporary (i.e., cross-sectional) PTSD network among mother-adolescent dyads after the Wenchuan earthquake. Another is to assess the causal relationships in symptom-symptom interaction in the temporal (i.e., longitudinal) PTSD network among dyads using CLPN models. We did not formulate specific hypotheses due to the limited evidence. Through our research, we aspire to offer actionable suggestions based on symptoms of a higher centrality, which can inform relevant interventions and policies.

2. Methods

2.1. Participants and procedures

On May 12, 2008, a catastrophic 8.0-magnitude earthquake struck Wenchuan County (Sichuan, China). The disaster caused 69,227 deaths, and 374,176 injuries, and left 18,222 individuals missing in the affected areas. To gain insight into the enduring mental health problems among adolescent survivors, our research team initiated the Wenchuan Earthquake Adolescent Health Cohort (WEAHC) six months after the catastrophe (Fan *et al.*, 2017). The WEAHC is a longitudinal study, with a focus on adolescent survivors in Dujiangyan city, one of the areas particularly devastated by the earthquake. The present study involved high school students and their mothers, examining WEAHC data at 12 months (T12m) and 18 months (T18m) following the earthquake. Initially, data were collected from 576 mother-adolescent dyads at T12m. Following a six-month follow-up period, 399 of these dyads were successfully recontacted and provided valid data for analyses.

The WEAHC study was approved by the Human Research Ethics Committee of the corresponding author's institution and was supported by the Women's Federation of Chengdu City, Sichuan Province, and the cooperative school boards. Written informed consent was obtained from all participants. Surveys were administered in the classroom under the supervision of teachers and investigators. Students completed self-reported measures, while mothers completed questionnaires at home following a detailed study explanation provided during school parent meetings.

2.2. Measures

2.2.1. Demographic and earthquake exposure

Maternal age and earthquake exposure were collected at 12 months. For adolescents, information on gender, age, and earthquake exposure was collected at the baseline (i.e., six months post-earthquake). Specifically, earthquake exposure was assessed by four items (family members' death, missing, and/or injury; house damage; property loss; and witness of tragic scenes). Each item was rated on a 5-point scale, with 1 representing the lowest level of exposure and 5 representing the highest. In this study, the total scores were summed (ranging from 4 to 20), and thus a higher score indicates greater earthquake exposure.

2.2.2. PTSD symptoms

The severity of PTSD symptoms in both mothers and adolescents at T12m and T18m was assessed using the Posttraumatic Stress Disorder Self-Rating Scale (PTSD-SS) (Liu et al., 1998). The scale consists of 24 items rated on a 5-point Likert scale, ranging from 1 (not at all) to 5 (extremely severe). Higher scores indicate a greater severity of PTSD symptoms (Liu et al., 1998). For the subsequent analyses, 15 items were chosen to align with the DSM-IV criteria for PTSD symptoms. The Cronbach's alphas of these 15 items for both adolescents and mothers at both time points ranged from 0.91 to 0.92.

2.3. Statistical analysis

To examine the pattern of missing data, a *t*-test was conducted using SPSS 26.0 to compare the mean severity of PTSD symptoms at 12 months between participants who provided complete data across both waves ($n = 399$) and those who were lost to follow-up ($n = 177$). Results indicated no significant differences between the two groups. Missing data were observed for maternal age (1.3%) and earthquake exposure (3.8%) as well as on adolescent earthquake exposure (7.3%). Little's Missing Completely at Random (MCAR) test was used to analyze the missing values in all variables. Results showed that the data were missing at random, $\chi^2(7) = 4.86$, $p = 0.68$. The expectation-maximization (EM) algorithm was employed to impute missing data for those variables. Descriptive statistics were calculated using SPSS 26.0. Contemporaneous and temporal network analyses were performed using R 4.2.1.

2.4. Network estimation

Firstly, we used the *goldbricker* function to identify overlapping correlations between maternal and adolescent symptoms. Items that were redundant with any other item (less than 25% of statistically different correlations) were excluded (Ma et al., 2022). Secondly, we assessed the contemporaneous and temporal networks. In the network, individual symptoms were represented as nodes, while the edges denoted the associations between these symptoms. The thickness of the edges represented the strength of the relationships, and the color of the edges indicated positive (blue) or negative (red) correlations.

In the contemporaneous networks, we estimated the network structure using the R-package *qgraph* (Version 1.9.2) with Extended Bayesian Information Criterion graphical least absolute shrinkage and selection operator (EBICglasso) (Epskamp et al., 2012). The Fruchterman-Reingold algorithm in the R-package *qgraph* was used to visualize the network layout (Epskamp et al., 2012). To assess the importance of each symptom in the network, we used the expected influence (EI) centrality index. The EI is calculated by summing all edge weight values extending from a given node, reflecting its connectivity with the other nodes in the network (Robinaugh et al., 2016). Additionally, we identified symptoms that act as “bridges” connecting mother-adolescent networks. Bridge symptoms were evaluated based on their connections to the network of symptoms beyond their own community, such as the influence of each mother symptom on the adolescent symptom community and vice versa. The bridge expected influence (BEI) centrality index was used to

quantify bridge symptoms. Symptoms with $EI > 1$ and $BEI > 1$ can be considered as central and bridge symptoms, respectively (Sánchez Hernández et al., 2023). The *centralityPlot* function in the R-packages *qgraph* (version 1.9.2) and *networktools* (Version 1.5.0) was used to estimate these centrality indices. Previous research has also used EI and BEI values to identify central and bridge symptoms (Yuan et al., 2021).

In the temporal network, the least absolute shrinkage and selection operator regularization with 10-fold cross-validation was adopted. A higher cross-lagged out-EI indicated that a symptom at an earlier time point exerted a more substantial influence on other symptoms at the subsequent time point (Li and Kwok, 2023). Conversely, a higher cross-lagged in-EI signified that a symptom at a later time point was more influenced by other symptoms at the previous time point. To enhance interpretability, we utilized log odds ratios (ORs) to represent the edge weights. Thus, an edge weight greater than 1 indicates a positive relationship, an edge weight below 1 reflects a negative relationship, and an edge weight of exactly 1 indicates no relationship (Funkhouser et al., 2021). Given the relevance of demographic factors (age and gender) and earthquake exposure in influencing PTSD symptomatology in some studies (Chen et al., 2020), these variables were incorporated as covariates in our network analyses.

2.5. Network accuracy and stability

To assess the accuracy and stability of contemporaneous and temporal networks, we utilized the R-package *bootnet* with random 1000 “nonparametric” type and 1000 “case-drop” type bootstraps. Correlation Stability coefficients (CS-coefficient) of centrality indices above 0.50 are considered acceptable, with a minimum requirement of 0.25 (Epskamp and Fried, 2018).

3. Results

3.1. Sample characteristics

A total of 399 mother-adolescent dyads provided data at both 12 and 18 months. The adolescents (31.8% were males and 68.2% were females) had a mean age of 15.37 ($SD = 0.65$), with ages ranging from 13 to 17 years at the baseline. Mothers had a mean age of 40.30 ($SD = 4.23$) at T12m. The mean earthquake exposure scores for adolescents and mothers were 11.26 ($SD = 2.64$) and 9.05 ($SD = 1.56$), respectively.

3.2. Contemporaneous networks

3.2.1. Contemporaneous network structures and inference

Table 1 summarizes the network nodes of PTSD symptoms among mother-adolescent dyads. Figure 1 shows the contemporaneous network for mother-adolescent dyads at 12 and 18 months. The EI index (Figure 2) identified the following symptoms as central in the 12-month network: “loss of interest (M4)”, “intrusive thoughts (M2 & A2)”, “pessimism and disappointment (A13)”, and “flashbacks (A11)”. At T18m, the central symptoms were maternal “pessimism and disappointment (M13)”, “difficulty in concentration (M9)”, “trauma-related amnesia (M14)”, and adolescents’ “flashbacks (A11)” and “intrusive thoughts (A2)”. The BEI index (Figure S1) was not reported due to its unstable CS-coefficient as detailed in the subsequent sections.

3.3. Contemporaneous accuracy and stability of network

To ensure the accuracy of the network, supplement Figure S2 shows that the EI values remained stable even after dropping different proportions of the sample. The CS-C (correlation stability coefficient) for EI was 0.52 at T12m and 0.44 at T18m, indicating satisfactory stability for the EI index. The BEI values of both periods were 0, which fell below the recommended threshold of 0.25 for stability (Liang et al., 2022). This lack of stability suggests that the identified bridge symptoms may be less

Table 1
Network nodes of PTSD symptoms among mother-adolescent dyads

	Item	Construct/nodes	Mothers		Adolescents	
			12 months	18 months	12 months	18 months
			Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
1	Fear when thinking about disasters	Emotional cue reactivity	2.29 (1.12)	2.00 (1.04)	2.02 (1.03)	1.66 (0.88)
2	Unable to escape the scene of the disaster in one's mind	Intrusive thoughts	2.04 (1.07)	1.78 (1.01)	1.81 (1.00)	1.47 (0.81)
3	Having nightmares about the disaster	Nightmares	1.67 (0.87)	1.45 (0.72)	1.32 (0.67)	1.21 (0.57)
4	Loss of interest after the disaster	Loss of interest	1.65 (0.84)	1.45 (0.72)	1.52 (0.85)	1.35 (0.75)
5	Becoming emotionally distant from loved ones	Estrangement with relatives	1.26 (0.59)	1.30 (0.70)	1.33 (0.71)	1.18 (0.59)
6	Efforts to control disaster-related thoughts	Avoidance of thoughts	1.71 (0.89)	1.53 (0.76)	1.54 (0.84)	1.32 (0.67)
7	Hypersensitive or easily frightened	Exaggerated startle response	1.68 (0.87)	1.52 (0.80)	1.57 (0.90)	1.33 (0.75)
8	Sleep disturbance	Sleep disturbance	1.82 (0.99)	1.58 (0.83)	1.66 (1.00)	1.40 (0.80)
9	Difficulty in concentration	Difficulty in concentration	1.65 (0.81)	1.47 (0.71)	2.21 (1.08)	1.73 (0.98)
10	Avoiding scenarios or activities during disasters	Avoidance of reminders	1.62 (0.91)	1.50 (0.80)	1.42 (0.80)	1.27 (0.69)
11	Appear illusory and feel like a disaster is happening again	Flashbacks	1.62 (0.91)	1.43 (0.71)	1.57 (0.94)	1.34 (0.80)
12	Discomforts such as palpitations, sweating, chest tightness, etc	Physiological cue reactivity	1.58 (0.85)	1.42 (0.75)	1.39 (0.79)	1.18 (0.54)
13	Pessimism and disappointment	Pessimism and disappointment	1.43 (0.71)	1.31 (0.63)	1.79 (1.06)	1.40 (0.77)
14	Trauma-related amnesia	Trauma-related amnesia	1.61 (0.75)	1.55 (0.78)	1.70 (0.95)	1.45 (0.81)
15	Irritability or anger	Irritability or anger	1.80 (0.95)	1.62 (0.80)	1.93 (1.17)	1.53 (0.87)

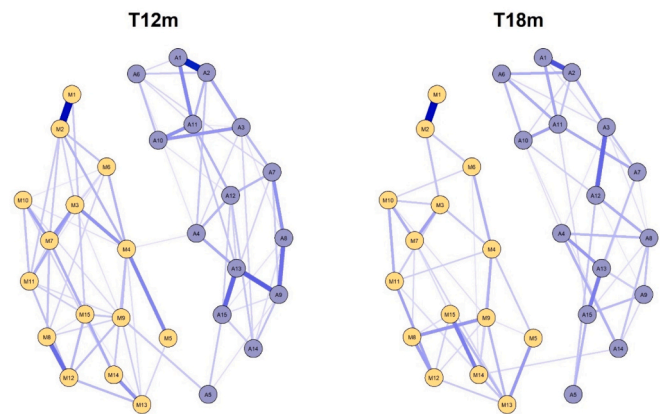


Figure 1. Contemporaneous networks of PTSD symptoms among mother-adolescent dyads at 12-month (T12m) and 18-month (T18m) after the 2008 Wenchuan earthquake ($N = 399$).
Note. A = Adolescents. M = Mothers. Specifically, 1 = Emotional cue reactivity; 2 = Intrusive thoughts; 3 = Nightmares; 4 = Loss of interest; 5 = Estrangement with relatives; 6 = Avoidance of thoughts; 7 = Exaggerated startle response; 8 = Sleep disturbance; 9 = Difficulty in concentration; 10 = Avoidance of reminders; 11 = Flashbacks; 12 = Physiological cue reactivity; 13 = Pessimism and disappointment; 14 = Trauma-related amnesia; 15 = Irritability or anger.
*Networks were adjusted for covariates (including demographic factors and earthquake exposure for both mothers and adolescents). These covariates were not presented in the figures to enhance clarity and ease of interpretation.

reliable. Thus, we presented results of all BEI values but did not offer further interpretations.

3.4. Temporal networks

3.4.1. Temporal network structures

The auto-regressive effects (mean $OR = 1.18$) were larger than the cross-lagged effects (mean $OR = 1.01$). Supplement Figure S3 shows the auto-regressive effects. The strongest auto-regressive effect was adolescents' "difficulty in concentration (A9)". The cross-lagged network results for PTSD symptoms in mother-adolescent dyads are shown in Figure 3. The strongest cross-lagged edge in the CLPN was adolescents' "nightmares (A3)" → "intrusive thoughts (A2)". Among the connections within the mother-adolescent dyads, adolescents' "nightmares (A3)" exerted the strongest predictive influence on maternal "loss of interest (M4)". This finding underscores the significant impact of adolescents' nightmares on the maternal symptom network.

3.4.2. Temporal network inference

The cross-lagged centrality results are depicted in Figure 4. The node with the highest out-EI was adolescents' "nightmares (A3)" (out-EI = 4.42). Some symptoms were found to have limited impact on other nodes but were greatly affected by other nodes (i.e., a high in-EI): "intrusive thoughts (A2)", "trauma-related amnesia (M14)", "irritability or anger (A15)", and "sleep disturbance (A8)". Centrality different tests showed that these symptoms differed from some other symptoms in the CLPN (Figure S4).

3.4.3. Temporal accuracy and stability of network

Bootstrapping revealed that the temporal network was stable in terms of out-EI (CS-coefficient=0.41), and in-EI (CS-coefficient= 0.31) (refer to Figure S5). The accuracy plots display confidence intervals around edge weights (refer to Figure S6).

4. Discussion

This study represents one of the pioneering attempts to utilize the network approach to model unique contemporaneous and temporal relationships of PTSD symptoms with mother-adolescent dyads after a catastrophic earthquake. Our findings reveal that in the contemporaneous network, "intrusive thoughts" in both mothers (M2) and adolescents (A2) and adolescents' "flashbacks (A11)" were central symptoms at almost both periods. "Pessimism and disappointment" for adolescents (A13) at T12m and mothers (M13) at T18m was central in the network. Maternal "loss of interest (M4)" at T12m and "difficulty in concentration (M9)" and "trauma-related amnesia (M14)" at T18m were central symptoms. In the temporal network, adolescents' "nightmares (A3)" had a high out-EI, indicating its predictive influence on other symptoms.

4.1. Contemporaneous networks

Regarding central symptoms, "intrusive thoughts" were a central symptom of mothers and children across nearly both periods. This aligns with the literature, which consistently identifies "intrusive thoughts" as a central symptom (Birkeland et al., 2020; Isvoranu et al., 2021; Ma et al., 2023). These intrusive thoughts may trigger a resemblance to the perceptual information of the traumatic experience, thereby eliciting PTSD symptoms akin to those experienced during the initial earthquake (Ma et al., 2023). The centrality of "intrusive thoughts" underscores the significance of trauma-related memories and intrusions in the development and maintenance of PTSD symptoms (Birkeland et al., 2020). Additionally, adolescent "flashbacks (A11)" consistently emerged as a central symptom across both periods, which echoes a four-year longitudinal study of Chinese children showing that "flashbacks" exhibited a

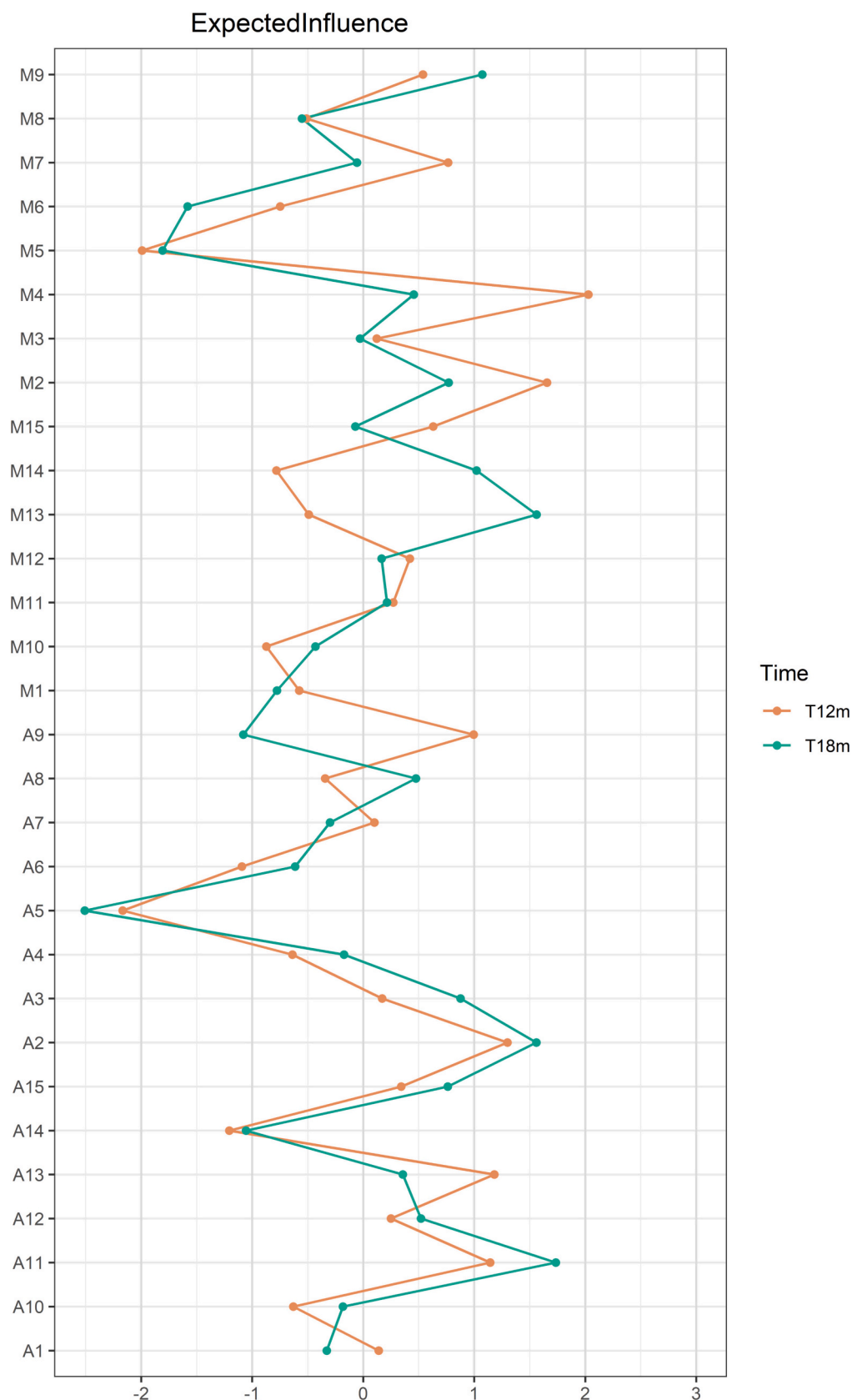


Figure 2. Expected influence of the network constructed by PTSD symptoms among 399 mother-adolescent dyads after the Wenchuan earthquake (standardized z-scores). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article).

Note. A = Adolescents. M = Mothers. Specifically, 1 = Emotional cue reactivity; 2 = Intrusive thoughts; 3 = Nightmares; 4 = Loss of interest; 5 = Estrangement with relatives; 6 = Avoidance of thoughts; 7 = Exaggerated startle response; 8 = Sleep disturbance; 9 = Difficulty in concentration; 10 = Avoidance of reminders; 11 = Flashbacks; 12 = Physiological cue reactivity; 13 = Pessimism and disappointment; 14 = Trauma-related amnesia; 15 = Irritability or anger.

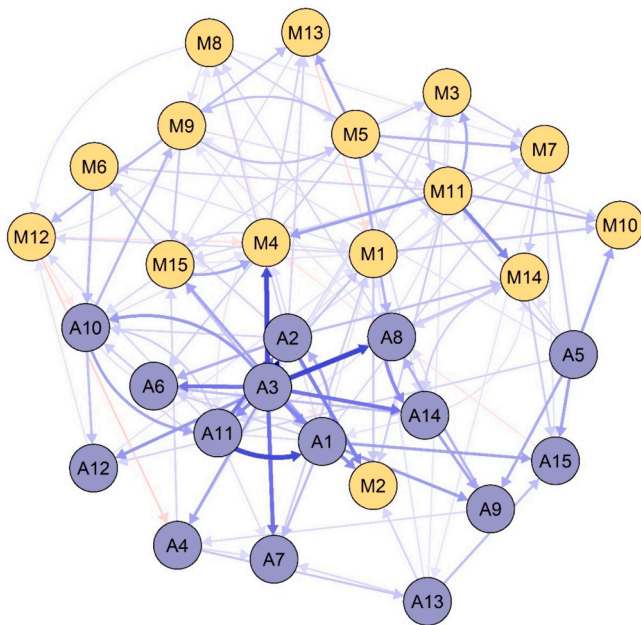


Figure 3. Temporal network of PTSD symptoms among mother-adolescent dyads ($N = 399$).

Note. A = Adolescents. M = Mothers. Specifically, 1 = Emotional cue reactivity; 2 = Intrusive thoughts; 3 = Nightmares; 4 = Loss of interest; 5 = Estrangement with relatives; 6 = Avoidance of thoughts; 7 = Exaggerated startle response; 8 = Sleep disturbance; 9 = Difficulty in concentration; 10 = Avoidance of reminders; 11 = Flashbacks; 12 = Physiological cue reactivity; 13 = Pessimism and disappointment; 14 = Trauma-related amnesia; 15 = Irritability or anger. *Networks were adjusted for covariates (including demographic factors and earthquake exposure for both mothers and adolescents). These covariates were not presented in the figures to enhance clarity and ease of interpretation.

relatively high centrality at all time points (Liang et al., 2020). Similar results were found in youth survivors exposed to the Lushan earthquake (Ge et al., 2019). These findings suggest that re-experience symptoms may play a pivotal role in the development, persistence, and treatment of PTSD (Ge et al., 2019). Furthermore, “pessimism and disappointment” of adolescents and mothers was central in the network. Feelings of helplessness and pessimism are likely to cause PTSD following a disaster (Guzel et al., 2024). Maternal “difficulty in concentration (M9)” was a central symptom. The central role of “difficulty in concentration” has also been confirmed in some previous work (Garabiles et al., 2020; Qi et al., 2023). Post-earthquake environments, such as their surrounding environmental damage and reconstruction, may impact survivors' ability to adjust and concentrate (Ma et al., 2023).

4.2. Temporal network

Our findings suggest that the longitudinal network (i.e., CLPN) provided additional information and was not a mere replication of a cross-sectional network (i.e., contemporaneous networks). Notably, adolescents' “nightmares (A3)” did not exhibit a high centrality in the contemporaneous networks but demonstrated a higher out-EI in the CLPN, indicating that it exerted a greater influence on subsequent other symptoms. Some literature has also shown that contemporaneous networks do not map straightforwardly onto the cross-lagged temporal network (Qi et al., 2023; Zainal and Newman, 2023). This disparity may stem from the self-reinforcing nature of symptom networks and autoregressive effects of the CLPN (Zainal and Newman, 2023). Consequently, separately examining contemporaneous and temporal networks is essential for acquiring a holistic and precise understanding of symptoms and their temporal evolution.

We found that adolescents' “nightmares (A3)” at T12m could

influence other symptoms at T18m. This is consistent with some previous studies suggesting that nightmares are a symptom with a higher centrality in the network (An et al., 2022; Eli et al., 2021). A longitudinal study found that sleep problems at 3 months had the highest out-expected influence centrality on symptoms at 15 months after the Zhouqu debris flow in China (Liang et al., 2022). Posttraumatic nightmares may involve the repetitive reexperiencing of traumatic events, often accompanied by heightened fear and negative emotions during the dream and upon awakening, which can lead to psychiatric distress and adverse outcomes, such as PTSD (Eli et al., 2021). Our current study further identified that adolescents' “nightmares (A3)” had the most predictive influence on subsequent “intrusive thoughts (A2)”. Additionally, adolescents' “nightmares (A3)” were identified as exerting the most predictive influence on the manifestation of maternal “loss of interest (M4)”, a finding that aligns with prior research highlighting the deleterious effects of children's sleep problems on maternal health (Hughes et al., 2015; Lollies et al., 2022). Several potential mechanisms may explain this relationship. Mothers of children with sleep disorders frequently endure compromised sleep quality (Lollies et al., 2022), which is associated with an increased risk of mental health issues (Chen et al., 2021). Consequently, this may result in a loss of interest in daily activities. Moreover, the presence of sleep problems in children and the resulting nighttime care responsibilities are associated with elevated levels of psychological exhaustion and reduced parental well-being (Hulst et al., 2021). The challenges of managing a child's sleep disruptions can pose substantial obstacles to parents' capacity to maintain their usual level of engagement in daily life, potentially resulting in a withdrawal of interest from various domains. Therefore, the significant impact of adolescents' nightmares on maternal loss of interest underscores the profound effects of children's sleep difficulties on maternal health. In summary, post-earthquake nightmares should be promptly addressed, as chronic or delayed dysfunctional nightmares in adolescence are significantly predictive of PTSD, even up to 10 years following the earthquake (Wang et al., 2023).

4.3. Implication

Our findings hold important theoretical and clinical implications. A pivotal insight from our study is the identification of “intrusive thoughts” in both mothers and adolescents and “flashbacks” of adolescents as central symptoms. Additionally, we identified maternal “difficulty in concentration” and “pessimism and disappointment” in both adolescents and mothers as pivotal symptoms. All these key symptoms are potential targets for the treatment of PTSD symptoms. Interventions that focus on acceptance and attention, such as mindfulness techniques, could be employed to address these symptoms (Bryant, 2021; Yuan et al., 2021). In addition, the predictive influence of adolescent “nightmares” on subsequent PTSD symptoms underscores the importance of targeting nightmares to reduce overall PTSD symptomatology. A review has suggested that prazosin and image rehearsal therapy should be considered as the initial choice of interventions for trauma-related nightmares (Zhang et al., 2022).

4.4. Limitation

The present study has several strengths, including the inclusion of mother-adolescent dyads and the examination of a dynamic network of PTSD symptoms following the earthquake. However, some limitations should also be acknowledged. First, all measures relied on self-report questionnaires, which may have introduced reporting bias. Future studies could benefit from additional assessment methods, such as clinician-administered interviews, to obtain a more comprehensive comprehension of PTSD symptoms. Second, our analysis is exclusively on earthquake survivors, and it is possible that different trauma types, such as natural disasters versus man-made disasters, may exhibit distinct symptom networks (Benfer et al., 2018). Finally, the current study

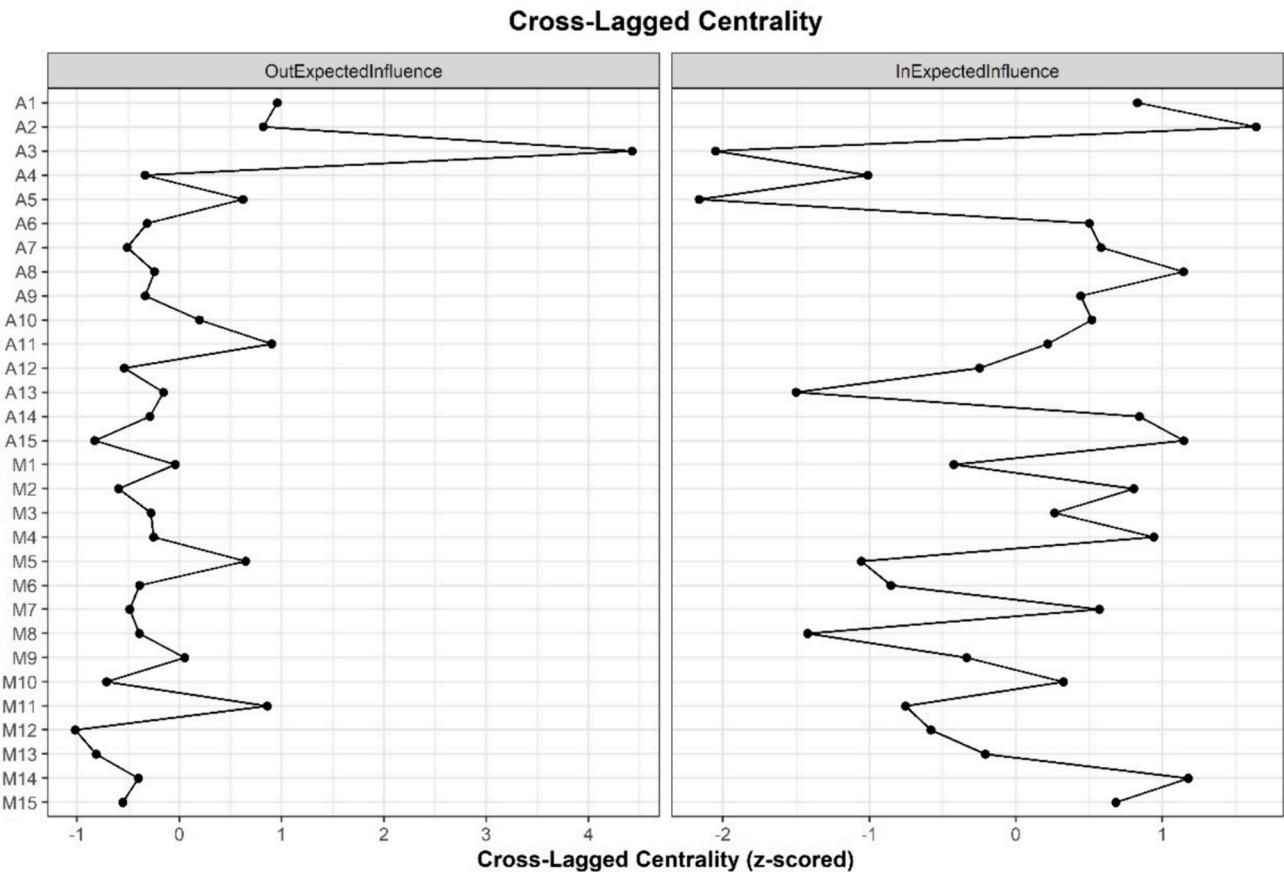


Figure 4. The out-EI and in-EI in the temporal network (N =399).

examined PTSD symptoms using the DSM-IV criteria, in line with the methodology of earlier research (Ge *et al.*, 2019). The choice to adhere to the DSM-IV rather than adopt the DSM-V was necessitated by the timing of our data collection, which occurred after the 2008 earthquake when the DSM-V was not yet available. It is important to highlight that there are some differences between the DSM-IV and DSM-V criteria, particularly in certain symptom clusters such as negative alterations in cognition and mood (APA, 2013). These discrepancies may have implications for the structure and understanding of the PTSD symptom network. Therefore, the findings of our study should be interpreted with caution, recognizing that the symptomatology defined by the DSM-IV may not fully align with the more contemporary understanding of PTSD as outlined in the DSM-V. To enhance the applicability and accuracy of future research, future studies are recommended to employ the most current diagnostic criteria. This will not only contribute to a more nuanced comprehension of PTSD but also facilitate more effective diagnostic and treatment strategies for those affected by PTSD.

5. Conclusions

This study is the first to investigate the network structure and dynamic changes of PTSD symptoms in mother-adolescent dyads affected by an earthquake. In contemporary networks, “intrusive thoughts” were identified as a central symptom for both mothers and adolescents, alongside “flashbacks” observed in adolescents. Additional central symptoms such as maternal “difficulty in concentration” and “pessimism and disappointment” of the dyads warrant consideration. In addition, the temporary network did not directly replicate the contemporary networks, as adolescents’ “nightmares” had a high influence on subsequent PTSD symptoms. These findings offer valuable insights for the design of interventions and treatments aimed at addressing comorbid

PTSD in mother-adolescent dyads.

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Ethical approval

The present study was approved by the Human Research Ethics Committee of South China Normal University and was supported by the Women’s Federation of Chengdu City, Sichuan Province, and the participating school boards. All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee.

Informed consent

Written informed consent was obtained from all participants.

CRediT authorship contribution statement

Xiao-Yan CHEN: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Conceptualization. **Chao Li:** Writing – review & editing, Visualization, Software. **Fang Fan:** Supervision, Resources, Project administration, Funding acquisition.

Declaration of competing interest

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

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jad.2024.09.045>.

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