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ORIGINAL RESEARCH

Symptomatic Pathways of Comorbid Depression, Anxiety, and Stress Among Adolescents Exposed to Childhood Trauma—Insights from the Network Approach

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Background: Childhood trauma can have a long-lasting influence on individuals and contribute to mental disorders, including depression and anxiety. Depression, anxiety, and stress are highly comorbid among adolescents with the trauma experience. Yet, the evolution of comorbidity remains unclear. To fill this gap, the current study aimed to explore the symptomatic and changing patterns of depression, anxiety, and stress among adolescents exposed to childhood trauma.

Methods: A total of 1548 college students (females = 782 (50.98%), $Mean_{age}$ = 19.59, SD_{age} = 1.14) in China completed the Childhood Trauma Questionnaire (CTQ) and the Depression, Anxiety, and Stress Scales (DASS-21), and 942 students (Females = 516 (54.78%), $Mean_{age}$ = 19.57, SD_{age} = 1.16) met the selection standard based on the cut-off scores of the CTQ. The symptomatic network and directed acyclic graph (DAG) network approaches were used.

Results: The results revealed that males reported experiencing significantly more physical abuse, physical neglect, emotional neglect, and sexual abuse compared to females. However, females scored significantly higher than males on "Worried" (DASS9), "Agitated" (DASS11), "Panic" (DASS15), and "Scared" (DASS20). No significant difference between genders was observed in the network structure and global strength. Meanwhile, among all participants, "Down-hearted" and "Agitated" appeared to be the most interconnected symptoms, the bridge symptoms in the symptom network, as well as the most vital symptoms in the directed acyclic graph network. Apart from that, "Panic" also served as the most prominent symptom in the directed acyclic graph network.

Conclusion: The results suggested that intervention targeted at assisting adolescents in developing more adaptive coping strategies with stress and regulating emotion could benefit the alleviation of comorbid depression, anxiety, and stress.

Keywords: childhood trauma, depression, anxiety, stress, symptom network

Introduction

Depression, anxiety, and stress are common among adolescents.[1] Previous studies have found that depression, anxiety, and stress can greatly influence adolescents' academic performance and social function[2] and even lead to a higher risk of suicide.[3] During adolescence, individuals experience rapid physical, cognitive, emotional, and social development.[4] It is crucial for adolescents to develop positive self-esteem, stable and healthy relationships, and adaptive coping and regulation strategies during this period.[4] Indeed, adolescence is a sensitive period for the onset of social-emotional disorders, including depression, anxiety, and stress.[5] Alarmingly, depression, anxiety, and stress tend to co-occur and can cause more serious impairment,[6] which has garnered significant attention.[7–9]

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However, the evolution of comorbidity remains unclear. There exist studies that found anxiety generally preceded the occurrence of depression[10] and could accurately predict later depression,[11] indicating that the occurrence of depression can be viewed as a more severe outcome of unresolved anxiety. Meanwhile, studies also declare a bidirectional relation between depression and anxiety,[12] suggesting that deflection in depression predicted later deflection in anxiety, and the reverse is also proven to be true.[13] One explanation for the discrepancies could be that both pathways (impairment caused by anxiety caused later depression or depression predicted subsequent anxiety) exist and may operate depending on specific anxiety disorders or developmental changes, such as traumatized experiences.[14] Indeed, the pathway linking anxiety, stress, and depression needs to be discussed among populations sharing similar experiences and deserves further exploration.

Childhood trauma, which encompasses physical, emotional, and sexual abuse, as well as physical and emotional neglect, is prevalent around the world. According to a recent meta-analysis, more than one-third of children around the world have experienced childhood trauma.[15] More specifically, another meta-analysis revealed that the prevalence rate of childhood trauma reached 64.7% among adolescents in China.[16] Alarmingly, childhood trauma has been recognized as an important risk factor for global public health and social welfare[17] as well as the vital risk factor for mental problems, including depression, anxiety, and stress.[18,19]

According to the stress theory, serious stressors, such as childhood trauma, can induce prolonged physiological activity through perseverative cognition,[20] which may manifest as increasing emotional reactions,[21] poorer coping strategies,[22] higher level of internalized shame,[23] and increasing sensitivity to later life stressors,[19] accumulating into anxiety, stress, and depression. In line with the theory, increasing studies have suggested that childhood trauma can increase the risk of various mental illnesses in later life, including depression,[24] anxiety,[25] stress, and their comorbidities.[26] Meanwhile, a systematic review suggested that the diagnosis of depression among children and adolescents exposed to childhood trauma is 2.6 times greater than those not exposed to childhood trauma,[27] which further highlights the fact that childhood trauma can contribute to unfavorable mental outcomes. In line with this, a 4-year longitudinal study revealed that exposure to childhood trauma may be a factor in developing negative self-evaluation, poorer resilience, and higher levels of neuroticism. Consequently, this can lead to increased depression severity during late adolescence.[18]

Despite being informative, the previous studies, perceiving the traditional perspective, view depression and anxiety as existing entities.[21,26,28,29] However, it is noticeable that depression, anxiety, stress, and other mental disorders consist of various symptoms that can be triggered by other symptoms.[30] Hence, the previous studies failed to answer the question of how the symptoms of depression, anxiety, or stress among traumatized individuals interacted with each other, exacerbating the severity or prompting comorbidity. This gap may hinder us from deepening our understanding of the underlying mechanism of depression and anxiety.

Apart from that, the relationship between childhood trauma and depression may differ between males and females.[31,32] As a previous study stated, males tend to report a higher history of childhood trauma compared to females[33] and show more deficits in first-episode psychosis, which is closely related to social cognition and emotion regulation.[34] Similarly, a recent study revealed that the relationship between childhood trauma and emotion dysregulation is stronger in males than females,[35] which is closely related to the maintenance and aggravation of depression.[36] On the contrary, there are also studies indicating that females exposed to childhood trauma may face a higher risk of depression and show more unfavorable outcomes compared to males.[32,37] The diverse findings in gender difference could be partly attributed to the cultural differences considering studies conducted in Western countries (such as Canada and the USA) suggesting that males showed more adverse outcomes,[34,35] while studies conducted in eastern Asian countries (such as China) hold the opposite perspective.[32,37] Notably, studies conducted in the Eastern Asian cultural context fail to answer the question of how depression or comorbid depression, anxiety, and stress differ among males and females, either from a symptomatic perspective or from the developing mechanism. Indeed, exploration to further clarify the diversity in depression, anxiety, and stress between males and females, especially in the Eastern Asian cultural context, is strictly needed.

Based on the symptomatic perspective, network analysis views symptoms as nodes and the correlations between symptoms as edges in the network, exploring the interactions between symptoms.[38,39] Hence, it enables a deeper

exploration of the influence caused by childhood trauma on the symptoms of depression, anxiety, and stress. However, studies using network analysis to explore the pathways of comorbid depression, anxiety, and stress among adolescents with childhood trauma are limited. Midolo, Santoro, Ferrante, Pellegriti, Russo, Costanzo and Schimmenti[29] explored the relationship between childhood trauma, attachment, and psychopathology in the network approach and found that emotional abuse was indirectly related to depression through anxious attachment. However, this study treated depression and anxiety as two separate nodes in this network, which still failed to clarify the influence caused by childhood trauma on the symptoms of depression and anxiety. More recently, a study explored the relationship between depression, sleep disturbance, and childhood trauma using the network approach and identified several bridge symptoms, including sleeping difficulty and daily dysfunction.[40] However, this study simply collected data through cluster sampling in a middle school and did not identify students who had experienced childhood trauma, limiting its guiding value for clinical intervention. Meanwhile, previous network analysis mainly focused on the relationship between depression and childhood trauma,[29,40,41] ignoring the prevalent comorbidity of depression, anxiety, and stress,[7–9] and failing to explore the possible symptomatic pathways in the comorbidity. Furthermore, none of the previous studies made a comparison between different gender groups who had experienced childhood trauma,[22,29,42] which may hinder clinical therapists in designing effective and suitable interventions for males and females.

Therefore, to address the limitations in the former studies and clarify the unique comorbid pathways of depression, anxiety, and stress among adolescents exposed to childhood trauma, the present study is conducted on adolescents with a history of childhood trauma to test the following hypotheses.

Aim 1: Identifying the most interconnected symptoms, the bridge symptoms, and the strongest correlations in the comorbidity network of depression, anxiety, and stress among adolescents exposed to childhood trauma.

Aim 2: Clarifying the Possible Symptomatic Pathway of the Comorbidity of Depression, Anxiety, and Stress.

Hypothesis 1: Previous studies found that the occurrence of anxiety usually precedes depression and recent anxiety can predict later depression.[10,11] Meanwhile, Shevlin, McBride, Murphy, Miller, Hartman, Levita, Mason, Martinez, McKay, Stocks, Bennett, Hyland, Karatzias and Bentall[43] found that trauma-related stress may induce anxiety and depression. Indeed, we hypothesize that symptoms of stress may trigger symptoms of anxiety and depression, and likewise, symptoms of anxiety could trigger symptoms of depression.

Aim 3: Exploring gender differences in the comorbidity of depression, anxiety, and stress among adolescents with the experience of childhood trauma.

Hypothesis 2: Previous studies have indicated that males tend to report a higher history of childhood trauma[33] as well as exhibit greater difficulties in regulating their emotions.[34] Based on our hypotheses, we anticipate that the comorbidity network will be denser and more closely linked among males.

Methods

Participants

With the sensitivity of the network setting as 0.6, we estimated the hypothesized sample size for the network model using the R package "powerly.".[44] As suggested by the result, 2228 samples are appropriate for the estimation of the network in the current study. Data collection was conducted between May and July 2023 in four cities in China: Nanjing, Guangzhou, Beijing, and Huaian. The assessment took place on an online platform called Wenjuanxing (https://www.wjx.cn/). We offered a hotline for free mental health services in the questionnaire as well as the contact information of the college psychological counselling center to ensure that if any circumstances about trauma or unexpected events, the participants are able to get help immediately. Participants completed two questionnaires: the Childhood Trauma Questionnaire[45] and the Depression, Anxiety, and Stress Scales.[46] The survey started with 4469 respondents, but after filtering out invalid responses who failed to pass the attention test item or those under the acute episode of diagnosed mental or physical disorders, only 3520 participants were left. To minimize the influence of careless responses which is common in online survey, we further used the responding time to identify the careless responders. Responders who failed to stay at one item less than 2 seconds were identified as the careless responders and removed from the dataset. Finally, a total of 1534 participants (females = 782

(50.98%), $Mean_{age}$ = 19.59, SD_{age} = 1.14) were included for further analysis. To classify participants based on their reported experience of childhood neglect or abuse, this study followed established guidelines from previous research conducted by Scher, Forde, McQuaid and Stein,[47] Subic-Wrana, Tschan, Michal, Zwerenz, Beutel and Wiltink,[48] and Walker, Unutzer, Rutter, Gelfand, Saunders, VonKorff, Koss and Katon.[49] Cut-off scores were used to determine the classification for each type of abuse or neglect. Specifically, a score of ≥8 was used to classify sexual abuse, a score of ≥10 for physical abuse, a score of ≥13 for emotional abuse, a score of ≥10 for physical neglect, and a score of ≥15 for emotional neglect. Noticeably, since in the current study, two items with low factor loadings were removed from the physical neglect subscale (for detail, see the first part of results), the cut-off score for physical neglect was adapted to 6.

Using these criteria, it was found that 155 students (10.10%) had experienced emotional abuse, 179 students (11.67%) had experienced physical abuse, 185 students (12.06%) had experienced sexual abuse, 340 students (22.16%) had experienced emotional neglect, and 821 students (53.52%) had experienced physical neglect. Notably, a total of 942 students (Females = 516 (54.78%), $Mean_{age}$ = 19.57, SD_{age} = 1.16) reported experiencing at least one type of childhood neglect or abuse and were included in the later analysis. Considering that the density of the network in psychology commonly varies from 0.1 to 0.3 which is lower than the default value of 0.4 in *powerly*, the current sample can still be substantial.

The purpose of the research was clearly explained to the participants through an electronic informed consent process before the assessment began. In addition, the study was thoroughly reviewed and approved by the ethics committee of the first author's university (reference number 202305290090).

Measures

Childhood Trauma Questionnaire (CTQ)

The childhood trauma questionnaire (CTQ) has 28 items and serves as both a clinical and non-clinical tool for assessing childhood trauma.[45] The CTQ assesses childhood memories retrospectively before the age of 16 and provides information on five subscales related to neglect and abuse. These subscales include emotional neglect, physical neglect, emotional abuse, physical abuse, and sexual abuse. Participants rate their experiences on a five-point Likert scale, ranging from 1 ("never true") to 5 ("very often true"). Higher scores on the CTQ indicate a higher extent of traumatic childhood experience. In the present study, Cronbach's α for the CTQ is 0.85. Considering the subscales, the Cronbach's α for the emotional abuse is 0.73, for physical abuse is 0.89, for sexual abuse is 0.94, for emotional neglect is 0.71, and for physical neglect is 0.60.

Depression, Anxiety, and Stress Scales (DASS-21)

The DASS is a psychological assessment tool consisting of three subscales comprising 42 items. It aims to measure the three-dimensional tripartite model of affect outlined by Lovibond and Lovibond,[50] namely, low positive affect (depression), physiological hyperarousal (anxiety), and negative affect (stress). Recently, a shortened version of the DASS has been developed,[46] consisting of 21 items (DASS-21). This shortened version has gained popularity among the general and clinical populations due to its robust psychometric properties and time efficiency when compared to the original 42-item version.[51] The Chinese version of the DASS-21 is well established,[52] and Cronbach's α is 0.96 in the present study. Considering the subscales, the Cronbach's α for depression is 0.90, for anxiety is 0.86, and for stress is 0.90.

Statistical Analysis

Confirmative Factor Analysis (CFA)

Before starting the network analysis, we first conducted the CFA on both scales used in the current study.

General Analysis Routine

Nodes Selection

Before conducting the network analysis, we utilized the *Goldbricker* function to assess item redundancy.[53] The analysis revealed that none of the items showed statistically significant redundancy, as indicated by correlations below 25% that were significantly different. Consequently, all items were included in the subsequent analysis.

Estimation Model

We estimated the partial correlation networks, which is also called the symptom network, for male, female, and all adolescents using the graphical Gaussian model, based R package *qgraph*.[54] The symptom network could provide us information about the co-occurrence of symptoms and clearly describe the symptom clusters in comorbidity. Furthermore, to provide information about the causal relation, the Bayesian model was employed to construct the directed acyclic graph (DAG) network, based on the R package *bnlearn*.[55] The DAG network could offer clues about the directed relation between symptoms, enabling the investigation into the changing process of comorbidity.

Accuracy and Stability of Edge-Estimates

To assess the stability and accuracy of the network model, we conducted the nonparametric bootstrap and the case-dropping bootstrap using the R package *bootnet*.[56] The correlation stability coefficient (CS-C) of the network model was calculated, and the confidence intervals (CIs) of edge weights and centrality indices were estimated.

Analysis-Specific Routine

Centrality Indices

We choose the Expected Influence (EI) to quantify how close a node is directly connected to other nodes. The EI value is calculated by the total of edge weights linked to a node. Considering that there exist negative edges in the current network, EI could better describe the degree that a symptom may prompt other symptoms.[57,58] Therefore, EI was chosen as the centrality indices to describe the importance of a node. Meanwhile, to better clarify the interaction between diverse disorders, we choose the Bridge Expected Influence (BEI) to assess how intense a node is related to other nodes in different communities.[59] The BEI was calculated by the sum of edge weights connected to the node and other nodes that belong to diverse disorder.

A more detailed description of the data analysis methodology can be found in the Supplementary Material.

Results

Descriptive Analysis and CFA

In referring to Peterson,[60] the factor loading should be higher than 0.4 to ensure the validity of the measurements. As stated by the CFA, two items in the physical neglect subscale of CTQ failed to meet the criterion of the standardized factor loading (CTQ-2: 0.228 and CTQ-26: 0.128). The CTQ-2 was described as "I knew that there was someone to take care of me and protect me" and the CTQ-26 was described as "There was someone to take me to the doctor if I needed it".[45] Since physical neglect is defined as failure to provide food, clothing, shelter and medical care,[61] the CTQ-2 could be less precise in assessing physical neglect. Apart from that, a recent meta-analysis exploring the prevalence of neglect of children in China, medical neglect is the least prevalent in China, especially in urban area.[62] Considering the current study sampled in urban university, it is reasonable to deduct that CTQ-26 cannot contribute to physical neglect. Therefore, we considered moving these two items to enhance the credibility of the current study. Apart from that, all items in DASS obtained factor loadings higher than 0.6. The standardized factor loadings for both CTQ and DASS-21 are shown in Figures S1–S3. The fit indices of the original CTQ as well as the modified CTQ are shown in Table 1, suggesting that after removing these two items, the model fits better on the current data.

The mean, standard deviation, and *t*-test results for the DASS-21 components comparing male and female students with childhood trauma are presented in Table 2. The results show that female students with childhood trauma scored

Table 1 The Results of CFA on CTQ

Model	RMSEA	CFI	TLI	χ^2	*df*	χ^2/df	SRMR
CTQ							
Original	0.083	0.878	0.862	3043.863	265	11.486	0.080
Removing CTQ-26	0.081	0.892	0.876	2267.231	242	9.360	0.072
Removing CTQ-2	0.071	0.922	0.910	1914.416	220	8.702	0.051

Table 2 Descriptive Analysis and *t*-Test

Variables		Male	Female	*p*
		N = 426	N = 516	
Age		19.6 (1.16)	19.5 (1.16)	0.320
Left Child				0.923
	Yes	33 (7.75%)	38 (7.36%)	
	No	393 (92.3%)	478 (92.6%)	
Only Child				0.245
	Yes	138 (32.4%)	148 (28.7%)	
	No	288 (67.6%)	368 (71.3%)	
Marriage				0.323
	Good	381 (89.4%)	457 (88.6%)	
	Divorce and Unmarriage	30 (7.04%)	31 (6.01%)	
	Divorce and Remarriage	15 (3.52%)	28 (5.43%)	
DASS1		1.89 (0.85)	1.87 (0.79)	0.745
DASS2		1.77 (0.82)	1.75 (0.77)	0.714
DASS3		1.64 (0.78)	1.61 (0.70)	0.507
DASS4		1.51 (0.74)	1.56 (0.71)	0.285
DASS5		1.99 (0.89)	1.93 (0.86)	0.349
DASS6		1.66 (0.74)	1.64 (0.70)	0.641
DASS7		1.62 (0.78)	1.58 (0.73)	0.436
DASS8		1.98 (0.93)	2.08 (0.93)	0.112
DASS9		2.34 (1.00)	2.47 (0.96)	<0.05
DASS10		1.91 (0.92)	1.88 (0.83)	0.601
DASS11		1.83 (0.86)	1.99 (0.89)	<0.01
DASS12		1.83 (0.90)	1.90 (0.85)	0.248
DASS13		1.75 (0.86)	1.83 (0.81)	0.152
DASS14		1.84 (0.86)	1.89 (0.84)	0.363
DASS15		1.50 (0.74)	1.62 (0.75)	<0.05
DASS16		1.60 (0.76)	1.61 (0.71)	0.768
DASS17		1.38 (0.67)	1.38 (0.65)	0.929
DASS18		1.65 (0.81)	1.72 (0.83)	0.199
DASS19		1.55 (0.75)	1.60 (0.74)	0.330
DASS20		1.49 (0.73)	1.59 (0.75)	<0.05
DASS21		1.49 (0.78)	1.48 (0.74)	0.909

significantly higher than male students with childhood trauma on "Worried" (DASS9), "Agitated" (DASS11), "Panic" (DASS15), and "Scared" (DASS20).

The detection rates of five different childhood traumas among the two genders are shown in Figure 1 and the *t*-test results for scores on subscales of CTQ comparing female and male students are shown in Table 3. The results show that the detection rates among male students are significantly higher than those among female adolescents for physical abuse, emotional neglect, and sexual abuse.

Network Estimation and Local Network Structure Properties

The structure of the symptom network is shown in Figure 2A. As illustrated in Figure 2A, the thickness of the edges is indicative of the edge weights. The greater the thickness of an edge, the stronger the relation between the two nodes. Of the potential 210 edges formed by 21 nodes, 67 are non-zero, representing 31.90%. The corresponding partial correlation matrix between students with childhood trauma is presented in Table S1. Notably, the strongest edges are related to depressive symptoms, specifically, the link between "Worthless" (DASS17) and "Meaningless" (DASS21) is strongest,

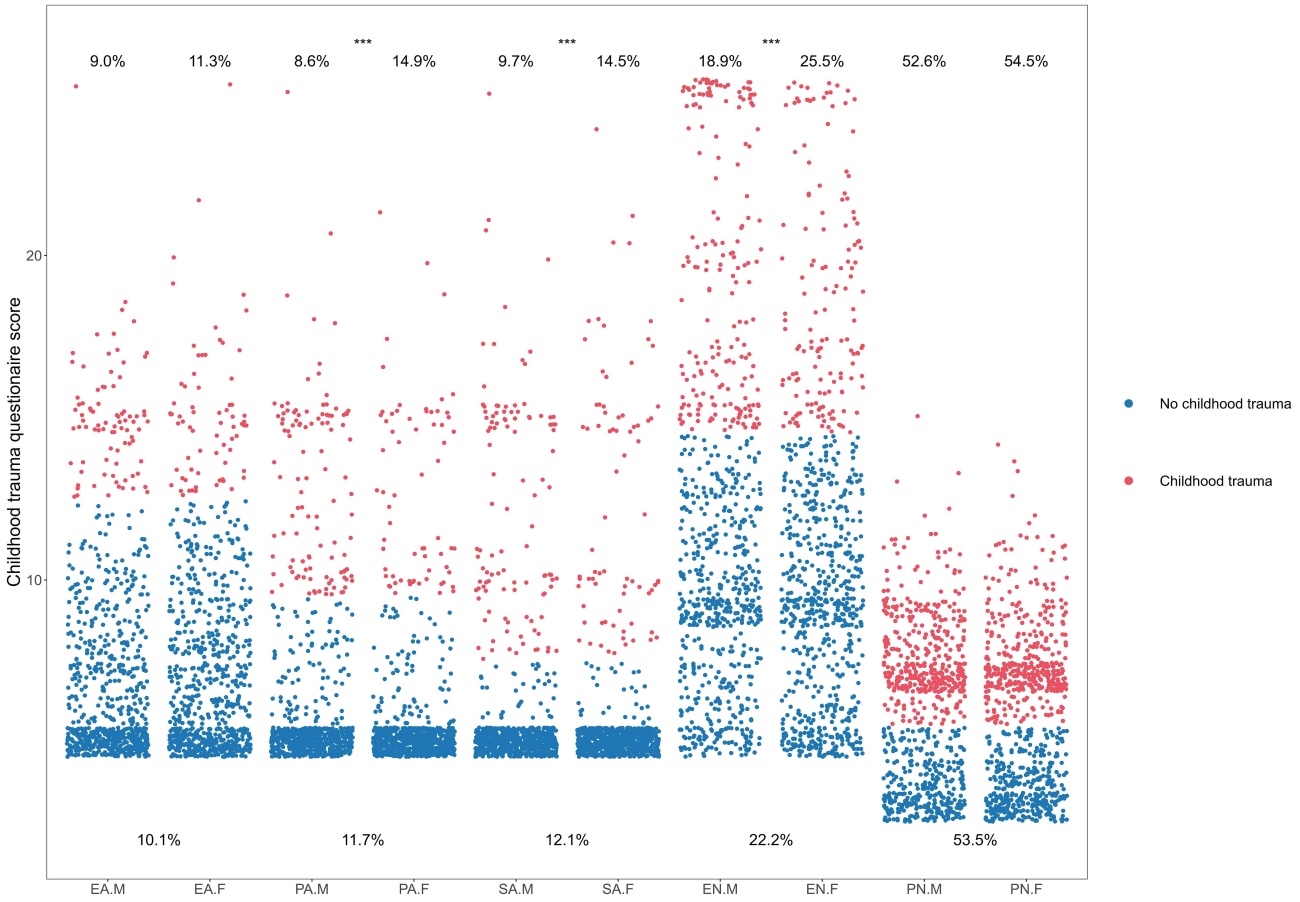

Figure 1 The detection rates of emotional abuse (EA), physical abuse (PA), sexual abuse (SA), emotional neglect (EN), and physical neglect (PN) among males (M) and females (F). *NS*: not significant; ***$p<0.001$.

and non-parametric bootstrapped difference tests indicate that this pairwise edge is significantly different from most remaining pairwise edges (Figure S4).

Centrality and Bridge measures Analysis

In Part B of Figure 2, the network analysis revealed that among students with childhood trauma, the highest nodes (EI) in the network were "Down-hearted" (DASS13), "Agitated" (DASS11), and "Meaningless" (DASS21), which also had a *Z*-score above 1. The non-parametric bootstrapped difference tests suggest that EI values of "Down-hearted" (DASS13), "Agitated" (DASS11) were significantly different from other 11 nodes within the network structure (Part C of Figure 2). On average, about 57.5% of the variance could potentially be explained by the influence of each node's neighbors ($M_{\text{predictability}} = 0.58 \pm 0.08$).

Table 3 t-Test of Subscales of CTQ Between Gender

	Male	Female	*p*
	N=1981	N=1617	
Emotional Abuse	7.42 (3.33)	7.54 (3.19)	0.484
Physical Abuse	6.48 (3.03)	5.89 (2.39)	<0.001
Sexual Abuse	6.14 (2.90)	5.79 (2.53)	<0.05
Emotional Neglect	11.7 (5.45)	10.7 (4.86)	<0.01
Physical Neglect	5.88 (2.31)	5.75 (2.27)	0.254

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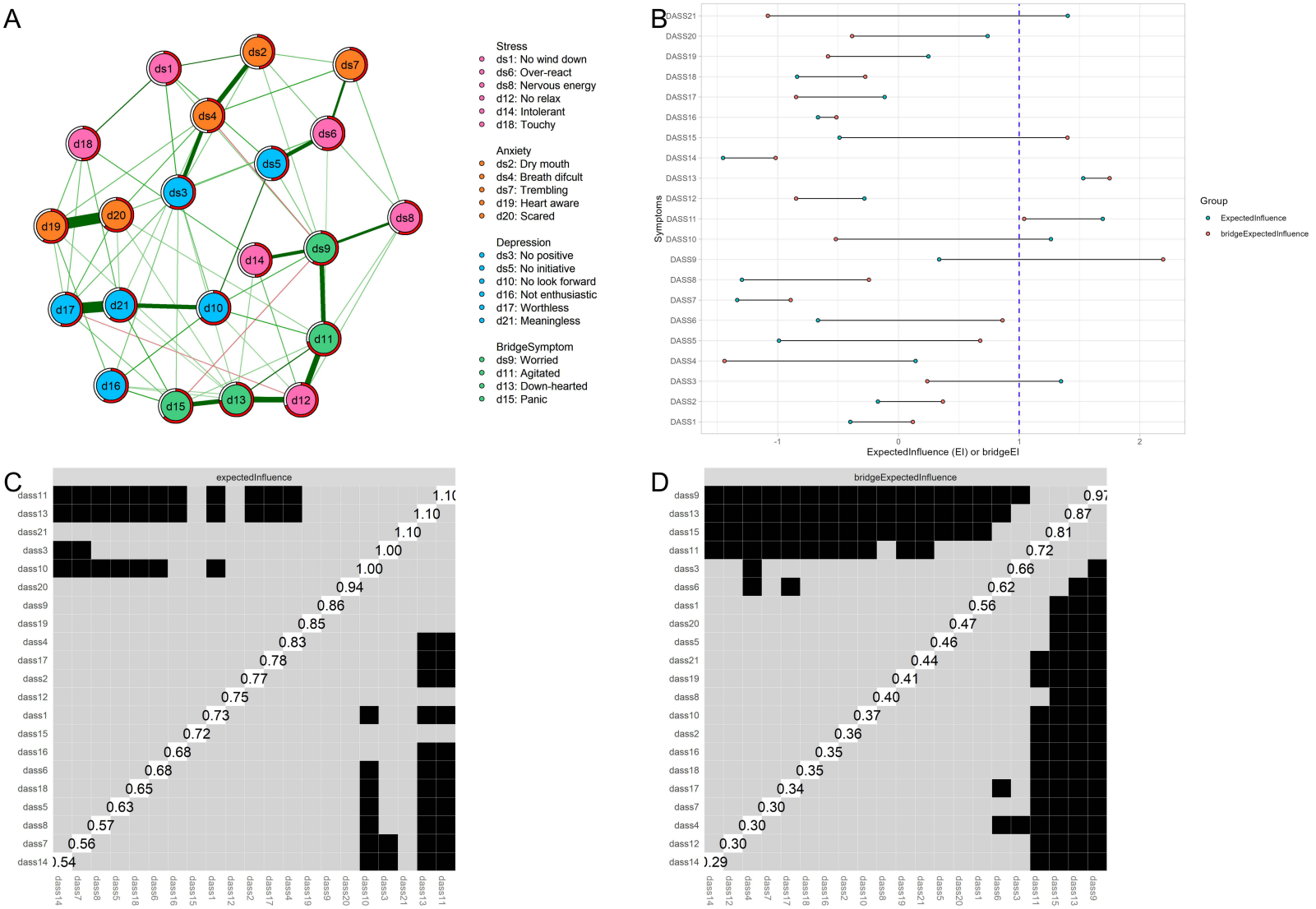

Figure 2 Network structure, standardized centrality, and bridge index (*Z* scores). (**A**) the stress-anxiety-depression network structure among adolescents with childhood trauma. (**B**) Expected Influence (EI) and bridge EI values for all nodes in the network among adolescents. (**C**) The non-parametric bootstrapped difference test for nodes' EI values in the network. (**D**) The non-parametric bootstrapped difference test for nodes' bridge EI values in the network.

Regarding the symptoms connecting the network of anxiety, depression, and stress in students with childhood trauma (as shown in parts A and B of Figure 2), the symptoms "Worry" (DASS9) and "Panic" (DASS15), which are related to anxiety, and "Down-hearted" (DASS13), which is related to depression, and "Agitated" (DASS11), which is related to stress, played a connecting role in students with childhood trauma. The non-parametric bootstrapped difference tests suggest that the four bridge EI mentioned above symptoms are significantly different from most remaining nodes within the network structure (Part D of Figure 2).

Network Stability

The non-parametric bootstrapped 95% confidence intervals (*CIs*) for the estimated edges were found to be narrow, indicating that the edges were reliable (see Figure S5). The case-dropping bootstrap procedure yielded a *CS-C* of 0.594 and 0.283 for EI and bridge EI in adolescents with childhood trauma, respectively (see Figure S6 for more details). According to Epskamp, Borsboom and Fried,[56] the *CS-C* should be greater than 0.25, and is preferably higher than 0.5. We concluded that the network is of acceptable stability.

Network Comparison Between Male and Female Adolescents With Childhood Trauma

We used the NetworkComparisonTest to assess the invariance of network structure and global strength between male and female adolescents with childhood trauma (see Figure S7). The results indicate an insignificant difference in network global network strength (9.91 vs 9.94; $S = 0.03$, $p = 0.879$) and network structure between males and females ($M = 0.19$, $p = 0.49$).

Directed Acyclic Graph (DAG) Analysis

In the DAG analysis (Figure 3), the nodes at the top of the figure may have the most influence on other nodes. In other words, these nodes could be seen as the trigger for other nodes. Therefore, in the current study, "Down-hearted"

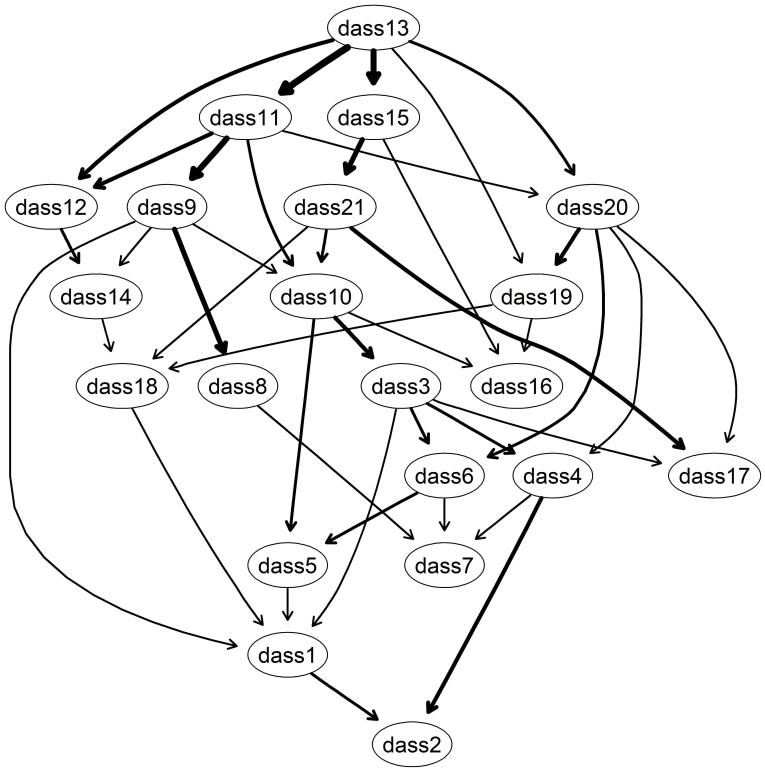

Figure 3 Directed acyclic graph (DAG) among adolescents with childhood trauma. Nodes represent symptoms, and edges represent directed connections between symptoms.

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(DASS13), "No-relax" (DASS12), and "Panic" (DASS15) emerged as the most pivotal network symptom in the stress-anxiety-depression network. In the DAG network, the thickness of the edge represents the importance of the edge. In other words, the magnitude of change that may ensue from the removal of an edge from the network is directly proportional to the thickness of the edge. Apart from that, the direction of the arc is determined by the proportion of the directional arc appearing in the total Bayesian simulation. Detailed information about the direction of the arc could be find in Table S2. Noticeably, the direction values between the most pivotal nodes are 80.90% (from "Down-hearted" to "Panic") and 61.15% (from "Down-hearted" to "No-relax"). These findings suggest that addressing "Down-hearted", "No-relax", and "Panic" may be crucial in effectively alleviating the stress-anxiety-depression symptoms in adolescents with childhood trauma.

Discussion

To the best of our knowledge, the current study is the first study to use network analysis to explore the comorbidity of depression, anxiety, and stress in adolescents who experienced childhood trauma. There are notable outcomes that merit discussion.

Gender Difference in the Mean Levels and Network Structure of Depression-Anxiety-Stress Among Adolescents Exposed to Childhood Trauma

The results indicated that the male detection rates of physical abuse, emotional neglect, and sexual abuse are significantly higher than those of females, which aligns with previous research[33] and partly supports our hypothesis 2. In Eastern Asian societies, male children may face greater parental expectations,[63] resulting in a higher likelihood of experiencing severe reprimands and corporal punishment,[64] which can be perceived as a kind of childhood trauma. However, the results of the *t*-test conducted between different gender groups demonstrated that girls scored significantly higher on "Worried" (DASS9), "Agitated" (DASS11), "Panic" (DASS15), and "Scared" (DASS20) than males. Noticeably, three of the mentioned symptoms belong to anxiety and the other symptom belongs to stress. This finding may suggest that despite the lower detection rate, females exposed to childhood trauma show a higher level of anxiety symptoms compared to males, which is partially supported by previous studies.[32,65]

One possible explanation may be that females exhibit a higher propensity for rumination and self-blame compared to males,[66] which acts as a mediator in the association between childhood trauma and mood indications.[67] Another possible explanation may lie in the fact that females respond differently to stressors compared to males.[68] According to Gershon, Minor and Hayward,[69] when confronted with childhood trauma, which is also characterized as a severe stressor, females tend to develop more internalizing problems (such as depression, stress, and anxiety), while males show more externalizing problems (such as aggression). Moreover, considering China has a long history of patriarchy and gender inequalities are still prevalent,[70] it is reasonable that females exposed to childhood trauma may have more difficulty in recovering due to fewer support resources or more discrimination.[71,72] Indeed, this finding raises the need for greater attention to effective intervention and adequate support for female adolescents with a history of childhood trauma.

Nevertheless, the network structure, global strength, and edge weights between the two groups do not show a significant difference, which overturns our previous hypothesis. Similarly, another study that utilized DASS-21 to chart the co-occurrence of depression, anxiety, and stress within the general population also concluded that there was no substantial variation in global strength based on gender.[73] This similarity may suggest that the overall pathological characteristics do not vary across the two genders. However, Van den Bergh, Marchetti and Koster Ernst[73] indicated that the network structure and some edge weights between genders showed some discrepancies, while the current study demonstrated no significant difference. This study was conducted on the general population with a wide age range (13–89), and a significant proportion of the participants (27%) were aged from 13 to 17.[73] Therefore, it is impossible to determine if they have experienced childhood trauma or not, as the childhood trauma questionnaire measures experiences before the age of 16. Differently, the current study is based on adolescents exposed to childhood trauma experiences. As mentioned earlier, childhood trauma can be viewed as an essential stressor in early life and may significantly increase victims' stress sensitivity.[19] Indeed, the comparable edge weights and network structure in the current study between the

two groups may suggest that the substantial impact of childhood trauma and concurrent developmental stage may supersede the influence of gender on the symptomatic interaction of depression, anxiety, and stress. This finding emphasizes the importance of preventing and addressing childhood trauma.

The Symptomatic Character of the Comorbidity Network of Depression, Anxiety, and Stress

Among all participants, it is worth noting that "Down-hearted" and "Agitated" served as the symptoms with the highest EI and the bridge symptoms in the symptom network. This finding suggests that these two symptoms share a close relationship with other symptoms of depression, anxiety, and stress, contributing greatly to their comorbidity.

"Down-hearted", described as "I felt down-hearted and blue", refers to a depressed mood most of the day, as indicated by subjective reports such as feeling sad, empty, and hopeless.[50] Meanwhile, despite being defined as a stress symptom, "Agitation" can also be seen as the manifestation of a depressed mood, especially among adolescents, according to the category of major depressive disorder in the Diagnostic and Statistical Manual of Mental Disorders-5 (DSM-5).[74] Therefore, this finding highlights the significant interconnecting role depressed mood plays in the comorbidity of depression, anxiety, and stress. However, another study mapping the interplay between depression, anxiety, and stress found that symptoms related to depressed mood do not have a significant influence.[73] Part of this diversity could be attributed to the heterogeneity of the samples. Van den Bergh, Marchetti and Koster Ernst[73] conducted their study on the general population, while the current study is based on traumatized adolescents. Therefore, the diversity in findings may suggest that depressed mood is a unique symptomatic characteristic in the comorbidity of depression, anxiety, and stress among adolescents with childhood trauma. As mentioned in the introduction, an empirical study has shown that individuals who have experienced childhood trauma tend to develop adverse cognition, paying more attention to negative stimuli in the environment,[28] and recollect more detailed negative events and fewer positive events.[75] It is reasonable that adolescents who have experienced childhood trauma are more likely to be stuck in a depressed mood due to their biased attention toward negative stimuli and triggered negative memories.[76]

More specifically, in the symptom network, "Down-hearted" and "Agitated" show a close relationship with anxiety symptoms such as "Worried" and "Panic", as well as stress symptoms such as "No-relax". This connection further emphasizes the interconnecting effect of depressed mood in comorbid depression, anxiety, and stress. Indeed, interventions targeting the depressed mood may help to deactivate the associations between symptoms and dissociate the comorbidity.[77] This finding highlights the necessity of designing proper interventions targeted at the negative mood state of adolescents with a history of childhood trauma.

Considering the interaction between symptoms, the results show that the strongest connection exists between "Meaningless" and "Worthless". "Meaningless", described as "I felt that life was meaningless" in the scale, refers to a state of perceiving one's life as lacking purpose, coherence, and significance.[78] On the other hand, "Worthless", described as "I felt I wasn't worth much as a person", is closely related to low self-evaluation.[79] The co-occurrence of the devaluation of life and self-deprecation might serve as another vital symptomatic characteristic among traumatized adolescents, which is consistent with previous studies.[80,81] Childhood trauma, especially emotional neglect and abuse from primary caregivers, can erode an individual's trust in their environment, leading to beliefs that they live in an unsafe, unfair, and meaningless world.[80] Additionally, the trauma experience may hinder adolescents from developing a positive and adaptive self-concept, increasing feelings of worthlessness.[81] It is noteworthy that "Worthless" and "Meaningless" can exacerbate the severity of depression and serve as important risk factors and predictors of suicide.[82–84] Therefore, it is crucial to assist adolescents with a history of childhood trauma in reconstructing the meaning of life and developing a more positive self-evaluation.

The Triggering Route in the Comorbidity Network of Depression, Anxiety, and Stress

Apart from that, it is worth noting that "Down-hearted" also appear to be the most prominent symptom in the DAG network. This finding may suggest that the comorbidity of depression, anxiety, and stress might start with a deteriorated

mood state. In detail, as the results of the Bayesian model suggested, "Down-hearted" contributed to the onset of "panic" under more than 80% circumstances. Noticeably, "Panic", referred as "I felt I was close to panic", could be seen as the signal for possible panic attack, which is a common symptom among individual exposed to traumatic event.[85] The directed relation from "Down-hearted" to "Panic" could be explained by the rising negative attention and memory bias connected with depressed mood state.[86] Robust evidence has proved that depressed mood state is closely related to the increased attention to the negative stimuli and decreased attention to positive stimuli.[87] Moreover, the augmented attention towards negative stimuli might skew the encoding and recalling process of memory,[88] leading to increased recalling of negative memory, such as the traumatic memory. Importantly, for those people with traumatic experiences, the fear of memories exactly served as the core of panic.[89] Therefore, the directed relation from "Down-hearted" to "Panic" is understandable.

Apart from that, "Down-hearted" is also related to "No-relax" under more than 60% circumstances. "No-relax", described as "I found it difficult to relax", may indicate a state of consistent alerting, which can also partly be attributed to the negative bias caused by the depressed mood. Orchard and Reynolds[90] discovered a significant association between depressed mood and negative interpretation, memory, and self-evaluation bias. This means that individuals trapped in a depressed mood tend to overestimate ambiguous stimuli and simultaneously underestimate their ability to cope with them, which may contribute to the onset of anxiety symptoms.[91]

In summary, the results partly disproved our hypothesis 1 and suggested that the comorbidity of depression, anxiety, and stress among adolescents with traumatized experience might emerge from depressed mood. The depressed mood might induce additional symptoms of anxiety and stress. Indeed, there are two possible ways to help maintain the mental health of adolescents exposed to childhood trauma: staying sensitive to the fluctuation of the mood state and strengthening their ability in adapting their mood state. More specifically, in schools, the current findings may indicate that teachers or school therapists could pay more attention to the fluctuation of mood state of students exposed to childhood trauma, especially in face with stressful events, such as important examinations. In clinics, our findings may suggest that when working with adolescents with childhood trauma experience, therapists could pay especially attention to guiding the development of effective emotion regulation methods for adapting the depressed mood.

Limitations

Several limitations of the current study need to be mentioned. First and foremost, due to the detection rate of childhood trauma and the deficiency of online data collecting, despite the current study started with more than 4000 participants, only 942 participants were left for the further analysis, which failed to reach the ideal sample size. Indeed, the results in the current study need to be interpreted with caution and request further testification by future research. Moreover, childhood trauma encompasses subtypes, namely emotional abuse, physical abuse, emotional neglect, physical neglect, and sexual abuse, which can have diverse impacts on mental health.[92] Therefore, further exploration is warranted to clarify the different influences caused by the five subtypes of childhood trauma. Meanwhile, the physical neglect subscale obtained a relatively low internal consistency in the current study as well as in other studies based on Chinese population.[93] Further revision on the Chinese version of childhood trauma questionnaire-short form is in urgent need. Additionally, considering that anxiety generally precedes the onset of depression,[10] longitudinal studies focusing on early and middle adolescents with childhood trauma are needed to elucidate the potential emerging process of stress, anxiety, and depression. The relatively low stability of the BEI values may be related to the diverse emerging procedure of the comorbidity of depression, anxiety, and stress, which warrants a deeper exploration. Furthermore, based on the chronic risk hypothesis proposed by Mu, Huang, Yao, Miao, Perlman, Watson, Klein and Kotov,[94] the prolonged duration of adverse events can significantly increase the risk of depression. Hence, the duration of childhood trauma should be taken into consideration in future studies. Apart from that, since all participants in the current study grow up in the Eastern Asia cultural context, further testification under cross-cultural backgrounds is needed. Last but not least, despite the fact that the DAG model could provide clues about the possible causal directionality in the comorbid depression, anxiety, and stress, the findings in the current study still need to be testified and strengthened by longitudinal or prospective assessment.

Conclusions

The current study uses the symptom network and DAG network to clarify the influence of childhood trauma on depression, anxiety, stress, and the interaction between different symptoms. The results showed that "Down-hearted" and "Agitated" served as the symptoms with the highest EI value, the bridge symptom, and the most prominent symptoms in the DAG network simultaneously. "No-relax" appeared to be the symptom with the highest EI value and the most prominent symptom in the DAG network. Moreover, the strongest edge exists between "Worthless" and "Meaningless". Apart from that, although females scored significantly higher on all symptoms except "Worthless" than males, the network structure and global strength do not differ from each other. Our findings suggest that interventions targeted at improving the mood state and coping strategies with stress among adolescents who have suffered from childhood trauma are strictly warranted. Additionally, it is also essential to assist in building the life's meaning and an adaptable self-image of adolescents who have experienced past childhood traumas.

Disclosure

The authors report no conflicts of interest in this work.

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