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Research Article

A Network Analysis of Gender Differences in PTSD Symptoms among Chinese Adults during COVID-19 Pandemic

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Background. The COVID-19 pandemic is by far the most significant public health crisis in the 21st century, arousing many psychological concerns like post-traumatic stress disorder (PTSD). *Aims*. This study is aimed at revealing gender differences and similarities in PTSD symptoms among Chinese adults during COVID-19 pandemic. *Methods*. Data used in this study were from an online cross-sectional study conducted in February 2020 via a web-based platform. We analyzed data from 558 Chinese adults (334 men and 224 women) with PCL-5 scores over the PTSD criteria. A network analysis was performed to explore the structure of PTSD symptoms for subgroups of men and women. *Results*. The results showed intrusive thoughts and emotional cue reactivity, together with negative beliefs and negative trauma-related emotions, presented strong positive connections in both men and women. A negative connection between intrusive thoughts and self-destructive/reckless behavior existed among women but not men. Regarding centrality symptoms, women and men had flashbacks and self-destructive/reckless behavior in common, but with differential orders. The most central symptom of PTSD was self-destructive/reckless behavior for women and difficulty concentrating for men. *Conclusion*. We urge that self-destructive/reckless behaviors and flashbacks, as potential core symptoms of COVID-19-related PTSD, be given more attention in future pandemic-related psychiatric intervention programs.

1. Background

The coronavirus disease 2019 (COVID-19), being regarded as a pandemic by the World Health Organization in March 2020, is one of the most significant public health problems in the 21st century. The impact of COVID-19 was multidimensional [1], mainly contributing to substantial psychological problems such as post-traumatic stress disorder (PTSD), depression, and anxiety [2, 3]. PTSD, as a leading psychological concern in the pandemic, consists of a series of symptoms, including avoidance, intrusion, excessive arousal, and emotional numbing [4]. Some researchers proposed that the sufferings of PTSD could be a continuum [5], and all these symptoms should be regarded as a whole to determine one person's position on this continuum. However, as noted by previous studies using the common reflective model [6, 7], the influence of each symptom on the outcome of PTSD may be distinguished [8]. That is to say, the structure and characteristics of PTSD could vary across scenarios given the differential expressions of the included symptoms.

Moreover, gender differences in PTSD have been frequently observed in previous studies [9, 10]. Recent research indicated that women might be at higher risk of developing PTSD following infectious diseases, and this gender difference occurred in the COVID-19-related PTSD [11]. When it comes to the gendered structure of PTSD symptoms, no consensus has been reached yet. For example, one study conducted among 79 female and 179 male veterans showed

that global functional impairment was associated with marked alterations in arousal and reactivity in women but with negative alteration in cognition and mood in men [12]. What is more, Birkeland and Heir [13] reported the different associations among PTSD symptoms between women and men; that is, woman could present higher level of symptoms. Based on previous studies, like gender theory, genders could have different presentations in many perspectives. For example, gender contributed to the differences of cognitive emotion regulation strategies and attribution styles [14], which might result in differences of the symptoms between genders, and females could be sensitive to intrusion symptoms compared to males. Also, some biopsychological differences could make contributions to the differences between genders as well; e.g., females could have more fear-induced sympathetic activation than males [15]. Thus, it might be rational for gender differences to occur regarding PTSD networks. However, on the contrary, another study claimed that there was no significant gender difference in the PTSD network, despite the existence of different central symptoms [16]. Though this inconsistency might partially be explained by differences in trauma types and exposure severity [17], whether the structure of COVID-19-related PTSD varies across gender still remains unclear, and the efficiency of psychological intervention depends greatly on this information. Thus, our study is aimed at further gender research in the PTSD network during the pandemic.

Briefly, this study is aimed at exploring the structure of COVID-19-related PTSD. Though it is based on Chinese sample, the discovery could shed light on future psychological interventions globally. Our aims are threefold: (1) estimating the network structure underlying the associations of PTSD symptoms from a gender perspective; (2) identifying the similarities and changes in network centrality measures across genders; and (3) finding potential connections between symptoms and core symptoms, which could be treated as target symptoms regarding prevention and intervention.

2. Materials and Methods

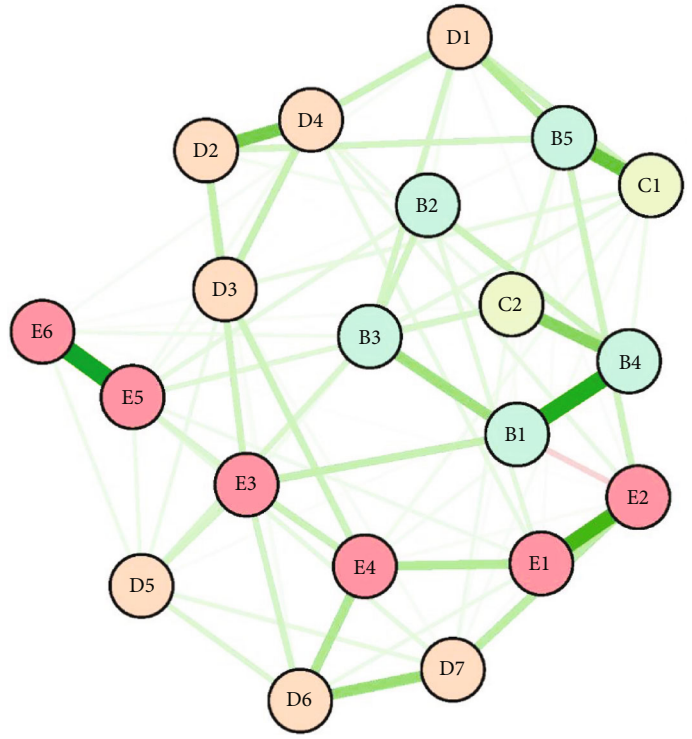
2.1. Participants. Data used in this study were from an online cross-sectional study conducted in February 2020 via a web-based platform (https://www.wjx.cn/app/survey.aspx). During the period of data collection (February 1, 2020), there were 11791 confirmed cases of COVID-19 reported in China. Based on self-report, all participants were required to answer an online questionnaire with regard to socio-demographic, psychiatric, COVID-19-related, and health-focused variables. Only participants who had no previous diagnosis of mental disorders and answered all the questions would be included. The exclusion criteria included less than 10 minutes of response time, confusion of logic, and age under 18 years. Finally, 2858 samples were valid. In this study, we included 558 participants who met the diagnostic criteria of PTSD as sample. In addition, according to previous studies [18, 19] and our current data, we took gender, age, depressive symptoms, sleep quality, and exposure to COVID-19 as covariates into consideration. Notably, all the participants were asked the questions in their native language. The details of the survey could be found in the previous study [20].

2.2. Measures

2.2.1. PTSD Symptoms. The COVID-19-related PTSD symptoms in the past month were assessed by the Post-traumatic Stress Disorder Checklist for DSM-5 (PCL-5; [21]). The PCL-5 contains 20 items, all of which were assessed with a 5-point Likert scale: 0 = not at all, 1 = a little bit, 2 = moderately, 3 = quite a bit, and 4 = extremely. The current sample's Cronbach's alpha was 0.97. According to the DSM-5, PTSD was divided into 20 individual symptoms in four groups: intrusions (IN; B1-B5 in Figure 1 in Results), avoidance (AV; C1-C2), negative alterations in cognition and mood (NACM; D1-D7), and alterations in arousal and reactivity (AAR; E1-E6) [21]. The diagnosis of PTSD currently requires trauma survivors to endorse a minimum of six symptoms (at least 1 IN, 1 AV, 2 NACM, and 2 AAR), except when reporting significant functional impairment and the persistence of symptoms for more than one month [21]. Accordingly, we formed the PTSD group from our data, with $N = 558$ (334 male, 224 female). Of note, there was no question associated with skip structures, which was mentioned as a requirement by Burger et al. [22] in their developed reporting standards of network analysis.

2.2.2. Depressive Symptoms. To assess depressive symptoms, we used the CES-D (Center for Epidemiological Survey-Depression) scale [23] to evaluate depressive symptoms during the past week. Previous studies had verified the validity and reliability of CES-D (Chinese version) in Chinese population, with satisfied concurrent validity and criterion validity [24, 25]. It is a 4-point scale with total scores ranging from 0 to 60, 0 = hardly ever or not at all, 1 = sometimes, 2 = usually, and 3 = always, with the higher scores indicating worse depressive symptoms. Among these items, items 4, 8, 12, and 16 were counted reversely. Cronbach's alpha of depressive in the current sample was 0.92, indicating considerable reliability. Due to network analysis method [8, 26], we used the total scores of all items to estimate the levels of depressive symptoms as previous study did [27].

2.2.3. Sleep Quality. We used the Pittsburgh Sleep Quality Index (PSQI) [28] to assess sleep quality; it is a 19-item self-rated questionnaire for evaluating subjective sleep quality over the past month. Previous studies had verified the validity and reliability of PSQI (Chinese version) in Chinese population with great psychometric properties, comparable to those of the original version [29, 30]. The 19 questions are combined into 7 clinically derived component scores, each weighted equally from 0 to 3. The 7 component scores are calculated together to form a score ranging from 0 to 21, with the higher scores indicating worse sleep quality. Similar to depressive symptoms, we used the total scores of each individual instead of dividing participants into different groups as previous study did [26, 31]. Notably, no participants were clinically diagnosed with sleep disorders before, and the Cronbach's coefficient is 0.694 in the current sample.



Intrusions
- B1: Intrusive thoughts
- B2: Nightmares
- B3: Flashbacks
- B4: Emotional cue reactivity
- B5: Physiological cue reactivity

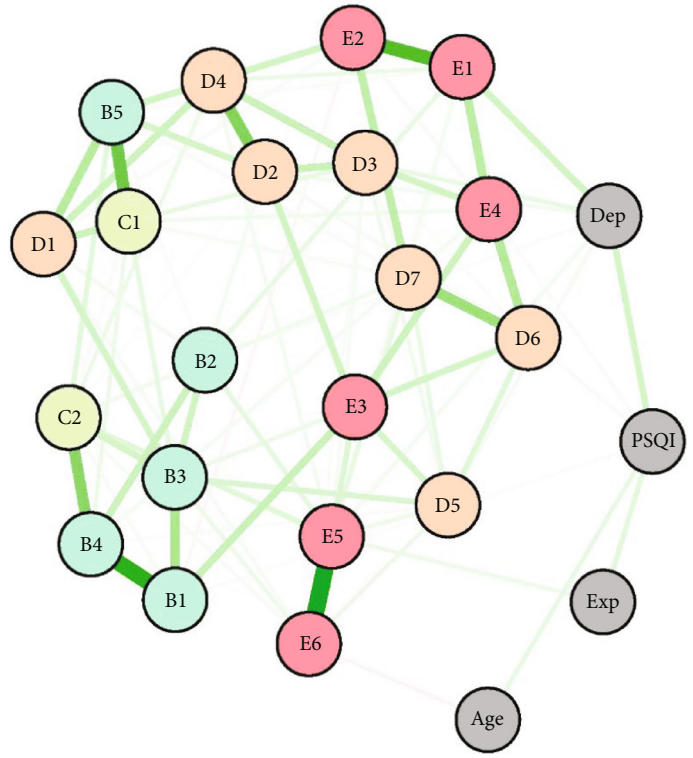
Cognition & mood alterations
- D1: Trauma-related amnesia
- D2: Negative beliefs
- D3: Blame of self or others
- D4: Negative trauma-related emotions
- D5: Loss of interest
- D6: Detachment
- D7: Restricted affect

Avoidance
- C1: Avoidance of thoughts
- C2: Avoidance of reminders

Arousal & reactivity alterations
- E1: Irritability/anger
- E2: Self-destructive/reckless behavior
- E3: Hypervigilance
- E4: Exaggerated startle response
- E5: Difficulty concentrating
- E6: Sleep disturbance

(a)

Figure 1: Continued.



(b)

Figure 1: (a) Network M1 containing the 20 DSM-5 symptoms of PTSD in the male subgroup. (b) Network M2∗ containing the 20 DSM-5 symptoms of PTSD and the covariates in the male subgroup.

2.2.4. Exposure to COVID-19. There were eight questions, containing two options, "yes" and "no," used to assess COVID-19 exposure: (1) were you infected with COVID-19, (2) have you had close contact with an infected person, (3) were your family members infected with COVID-19, (4) did a family member have close contact with the infected person, (5) were your relatives or friends infected with COVID-19, (6) did your relatives or friends have close contact with the infected person, (7) were your neighbors infected, and (8) is there an infected person in your community. Due to network analysis method, we regarded the option "yes' as 1 score and used the total scores of all items to estimate the levels of exposure (range = 0 – 8).

2.3. Data Analysis. All data analysis was conducted by R (version 4.1.0).

2.3.1. Network Estimation. We estimated the structure of networks via three stages based on the *R* package qgraph [26]. Before analysis, we formed the PTSD group from our data, with $N = 558$ (334 male and 224 female). In the first phase, all analyses were conducted among the PTSD male

subpopulation ($N = 334$). The first network (M1, Figure 1(a)) was generated from all 20 PTSD symptoms, and we added covariates into M1 to form M2∗ (Figure 1(b)) to investigate the impact of these covariates, which visualized the multivariate dependencies of the data. The Gaussian Graphical Model was used to estimate the 190 pairwise association parameters in M1 and 300 pairwise association parameters in M2∗. The connections (namely, edges, ranging from -1 to 1) among the nodes (symptoms and covariates) could be conceived as partial correlation coefficients, indicating the relationship between nodes A and B after controlling for the effects of nodes and other edges in the network. Further, to minimize the false-positive connections, we set very small edges to zero by the least absolute shrinkage and selection operator (LASSO) [32]. Also, we used the polychoric correlation to form networks, since PTSD symptoms and covariates in this study were ordered categorical. In the end, we removed covariates from the adjacency matrix of the 25-node network (M2), which resulted in the connections among the 20 PTSD symptoms controlling for covariates (M2∗). Finally, we derived a delta network (M3, see Figure M3 in Supplementary Materials) by subtracting this modified adjacency matrix M2∗ from the adjacency matrix of M1 (the 20 PTSD symptoms, not controlling for covariates), which contained the change of M1 upon including covariates, and examined the impact of the covariates on the connections between 20 PTSD symptoms. Of note, the exact numbers of these edges in A3 were meaningless to some degree. The aim of this analysis was to visualize the differences between networks, a method also used by other researchers [33].

In the second phase, we repeated the procedure in the female subgroup. The analysis revealed another three networks here: F1 (the 20 PTSD symptoms, Figure 2(a)), F2∗ (the 20 PTSD symptoms and covariates, Figure 2(b)), and F3 (the delta network of female subpopulation, see Figure F3 in the Supplementary Materials).

In the third phase, we followed Armour et al.'s [34] analysis method to examine the correlation between M1 and F1 (correlation coefficient: 0.32) to test whether the PTSD symptom network among the male and female subgroups was differential and correspondingly formed the delta network MF1 (see Supplementary materials). Of note, since the covariates had little influence on network, we compared the difference between genders without adding the covariates. Also, the edges of delta network (MF1) had little practical meaning to be discussed, which was simply used to visualize the difference between networks of these two subgroups.

2.3.2. Centrality Estimation. To indicate which symptoms might be the most representative for PTSD, centrality estimation was used. There were three graph-theoretical centrality measures [35]: (1) node strength: node strength sums all edges of one variable with all other variables, indicating the strength of a node connected with the network directly; (2) closeness centrality: closeness centrality calculates the inverse of all shortest path lengths of one node with all other nodes, thus showing how strong a node is associated with the network indirectly; and (3) betweenness centrality: betweenness centrality represents the frequency of one node lying on the shortest paths of any other two symptoms, indicating one node's ability to connect all other nodes in the network. Of note, we focused on node strength and its accuracy and stability in our study since the betweenness centrality and closeness centrality were unstable [36].

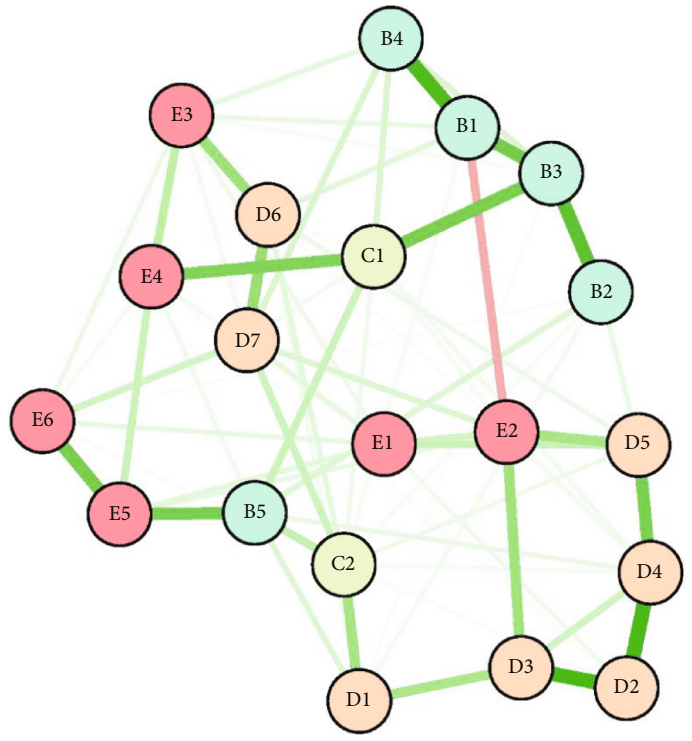
2.3.3. Accuracy and Stability Estimation. Because of a report of unclear stability and accuracy of network estimation [26], we bootstrapped (1000 iterations) the edge weights with estimations at a 95% confidence interval to test for significant differences between edge weights. We also calculated the correlation stability (CS) coefficient to assess the stability of the strength centrality, which should be at least 0.25 for the centrality to be stable, preferably above 0.5 [26].

2.4. Visualization. In our figures, we used the Fruchterman-Reingold algorithm [37] that places nodes with stronger (and/or more) connections more closely together. To be color-blind friendly, the positive edges were printed in green, whereas negative ones were in red. The stronger a connection was, the thicker and more saturated its line would appear. We used a minimum value of 0.03 in all networks except delta networks to enhance the interpretability of the graphs [34]. Of note, because of the tiny differences in delta networks, we set the minimum value as 0 in delta networks.

3. Results

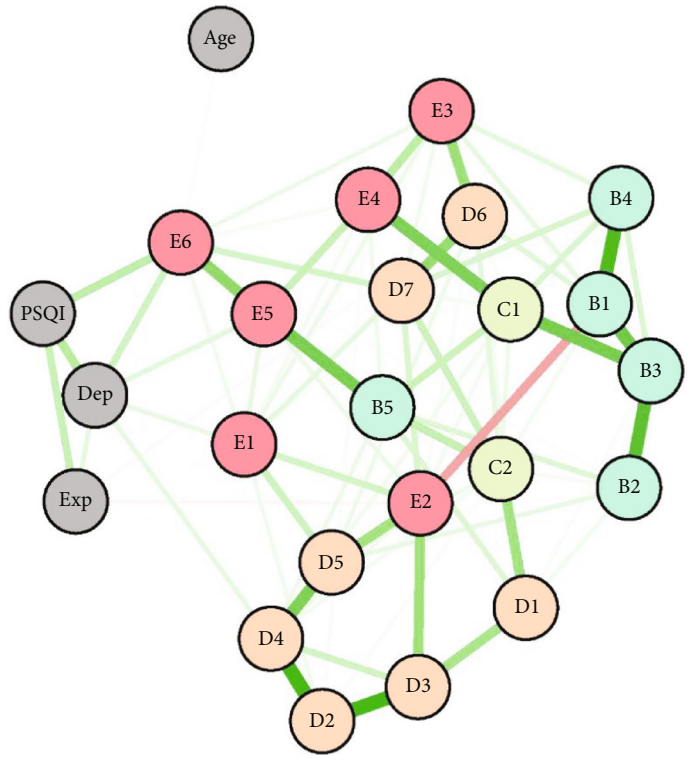
3.1. Sample Characteristics. Table 1 presents the details about each of the PTSD symptoms and the scores of covariates. Participants' ages ranged from 18 to >70 years. Females accounted for 40.1% of the whole PTSD group. The average scores of PTSD symptoms were 46.74 (SD = 12.57) in the whole PTSD group, 46.78 (SD = 12.89) in the male subgroup, and 46.68 (SD = 12.11) in the female subgroup.

3.2. Networks. Figure 1(a) represents the network M1 of the 20 PTSD symptoms among men. All connections between symptoms were positive. The five strongest associations between symptoms were difficulty concentrating (E5) and sleep disturbance (E6); intrusive thoughts (B1) and emotional cue reactivity (B4); irritability/anger (E1) and self-destructive/reckless behavior (E2); physiological cue reactivity (B5) and avoidance of thoughts (C1); and negative beliefs (D2) and negative trauma-related emotions (D4). Figure 1(b) shows the network structure M2∗ after adding covariates to the M1 network. It was necessary to indicate that connections in these networks could be understood as a partial correlation network, which meant the connections between covariates and symptoms should not be explained by the covariates among PTSD symptoms alone and the connections were mutual. After adding these covariates, the five strongest connections were the same as in M1. The coefficient between M1 and M2∗ was 0.9910, indicating a high correlation. Further, the sum of edges in this network reduced from 9.74 to 9.36 after controlling for covariates. That is, exposure accounted for 3.96% of the



(a)

Figure 2: Continued.



(b)

Figure 2: (a) Network F1 containing the 20 DSM-5 symptoms of PTSD in the female subgroup. (b) Network F2∗ containing the 20 DSM-5 symptoms of PTSD and the covariates in the female subgroup.

connectivity of the PTSD symptoms. The delta network M3 (see Figure M3 in the Supplementary materials) was nearly empty and featured a few very weak edges, with the strongest edge weight being only 0.025. In conclusion, the 20-item PTSD symptom network was robust whether the covariates were entered or not and remained largely unaffected, indicating that the connections might be stable and convincible in the male subgroup.

Figure 2(a) represents the network F1 of the 20 PTSD symptoms of the female subgroup. Expect intrusive thoughts (B1) and self-destructive/reckless behavior (E2) were negatively associated. All the other connections between symptoms were positive. The five strongest associations between symptoms were negative beliefs (D2) and negative trauma-related emotions (D4); blame of self or others (D3) and negative beliefs (D2); intrusive thoughts (B1) and emotional cue reactivity (B4); nightmares (B2) and flashbacks (B3); and intrusive thoughts (B1) and flashbacks (B3). After adding these covariates, Figure 2(b) shows that the five strongest connections in F2∗ are the same as in F1. The coefficient between F1 and F2∗ was 0.9914, also indicating a high correlation. The sum of edges in this network reduced from

Table 1: Description of post-traumatic stress symptoms and covariates.

	PTSD group ($n = 558$)		Male subgroup ($n = 334$)		Female subgroup ($n = 224$)		P value
	Mean	SD	Mean	SD	Mean	SD	
B1: intrusive thoughts	3.67	0.91	3.66	0.91	3.69	0.91	0.644
B2: nightmares	3.08	1.02	3.10	1.00	3.05	1.04	0.595
B3: flashbacks	3.40	0.93	3.40	0.95	3.39	0.91	0.918
B4: emotional cue reactivity	3.53	0.89	3.51	0.89	3.56	0.89	0.537
B5: physiological cue reactivity	3.25	0.91	3.25	0.91	3.25	0.91	0.985
C1: avoidance of thoughts	3.35	0.84	3.34	0.84	3.36	0.82	0.747
C2: avoidance of reminders	3.41	0.78	3.42	0.80	3.39	0.75	0.618
D1: trauma-related amnesia	3.29	0.89	3.28	0.92	3.29	0.84	0.940
D2: negative belief	3.28	0.89	3.30	0.89	3.26	0.90	0.628
D3: blame of self or others	3.25	0.88	3.24	0.87	3.26	0.90	0.753
D4: negative trauma-related emotions	3.26	0.91	3.25	0.93	3.29	0.87	0.653
D5: loss of interest	3.30	0.86	3.34	0.83	3.25	0.89	0.232
D6: detachment	3.42	0.84	3.44	0.85	3.38	0.84	0.442
D7: restricted affect	3.38	0.83	3.36	0.84	3.41	0.81	0.511
E1: irritability	3.30	0.87	3.28	0.90	3.33	0.82	0.513
E2: self-destructive/reckless behavior	3.14	0.96	3.18	0.98	3.09	0.92	0.316
E3: hypervigilance	3.44	0.84	3.43	0.84	3.45	0.84	0.818
E4: exaggerated startle response	3.30	0.85	3.28	0.88	3.33	0.81	0.494
E5: difficulty concentrating	3.34	0.83	3.35	0.85	3.32	0.80	0.614
E6: sleep disturbance	3.35	0.90	3.37	0.89	3.32	0.90	0.533
Depressive symptoms	29.03	10.88	29.78	10.75	27.91	11.01	0.045
PSQI	7.08	3.87	7.16	3.92	6.96	3.81	0.550
Exposure to COVID-19	0.81	1.60	0.69	1.41	0.98	1.83	0.051

Note: P values were calculated by differences between male and female groups.

9.76 to 9.68 after controlling for covariates, which means that exposure accounted for 0.83% of the connectivity of the PTSD symptoms. The delta network F3 (see Figure F3 in the Supplementary materials) was nearly empty and featured nearly no edge. In sum, the 20-item PTSD symptom network was robust, and the connections might be stable and convincible in the female subgroup.

Considering that the network is robust and the covariates have little influence on the network, we then examined the correlation between networks M1 and F1 to investigate the differences between males and females. The correlation was 0.32 and the delta network's (MF1) sum of edges of 20 symptoms was 10.46, with mean edge weight as 0.055 and max edge weight as 0.27 (the connection between the emotional cue reactivity (B4) and the trauma-related amnesia (D1)). These results indicated that there were considerable gender differences in the networks of COVID-19-related PTSD symptoms.

3.3. Centrality. The standardized estimates of centrality in the male subgroup are presented in Figure 3(a). Because the covariates showed little influence on the networks (*see Networks above*), we used only network M1 to investigate the centrality. The centrality estimates were substantially interrelated: correlation of 0.81 between closeness and betweenness, correlation of 0.60 between closeness and node strength, and correlation of 0.73 between node strength and betweenness. Because of these high intercorrelations and, as mentioned above, the greater stability of the node strength, we focused our interpretation of the most relevant symptoms on node strength centrality. As shown in Figure 3(a), the five nodes with the highest node strength were difficulty concentrating (E5), flashbacks (B3), physiological cue reactivity (B5), self-destructive/reckless behavior (E2), and emotional cue reactivity (B4), while the least central node, which had few and weak connections with other nodes, was nightmares (B2). All these results fitted the network in Figure 1(a).

The standardized estimates of centrality the female subgroup are presented in Figure 3(b). Centrality estimates were also substantially interrelated: correlation of 0.79 between closeness and betweenness, correlation of 0.66 between closeness and node strength, and correlation of 0.81 between node strength and betweenness. As Figure 3(b) shows, the five nodes with the highest node strength were self-destructive/reckless behavior (E2), avoidance of thoughts (C1), flashbacks (B3), intrusive thoughts (B1), and negative trauma-related emotions (D4), and the least central node, which had few and weak connections with other nodes, was nightmares (B2). All these results fitted the network in Figure 2(a).

3.4. Network Accuracy and Stability. The accuracy and stability of the 20 PTSD symptom network (M1) in the male

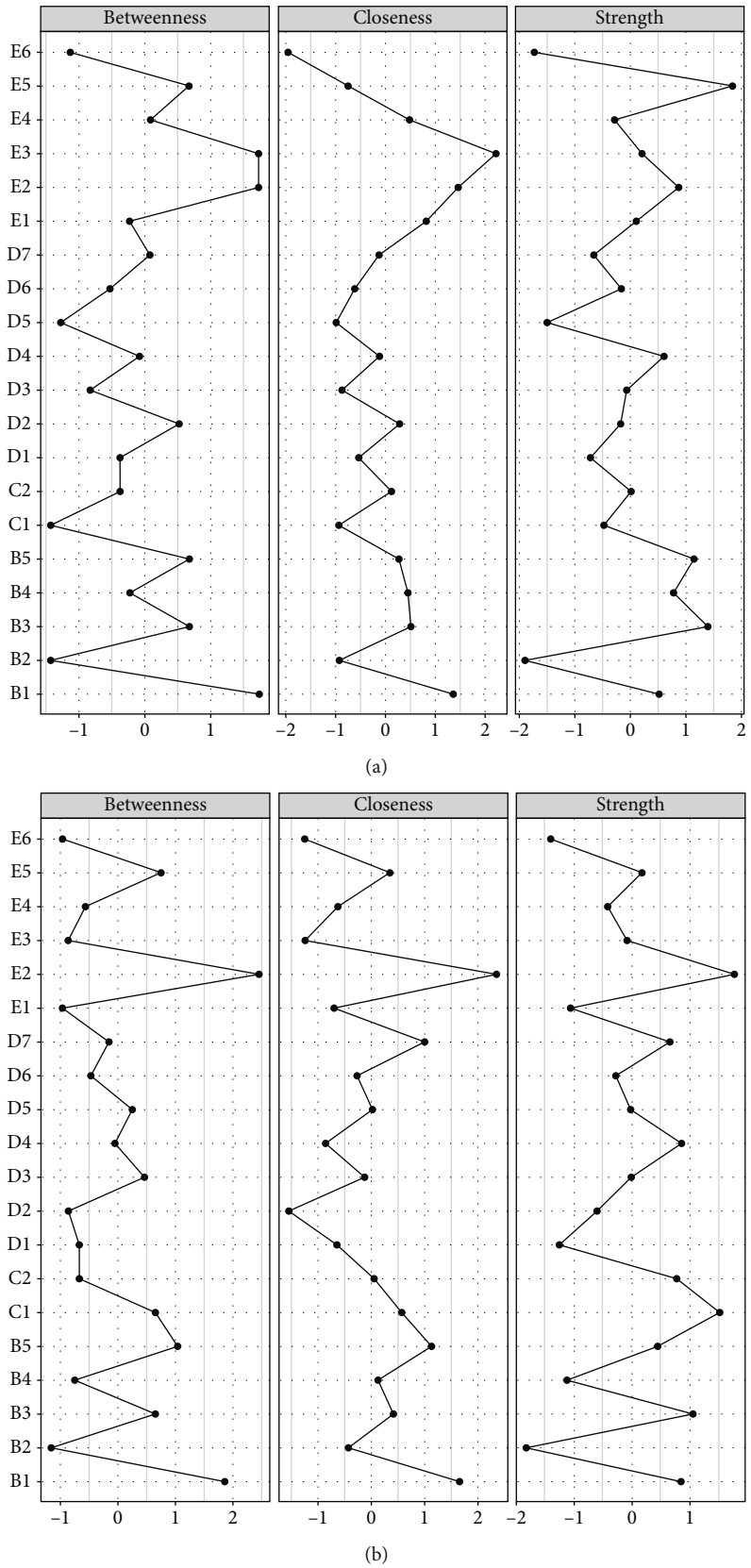


Figure 3: (a) Node strength centrality estimates for the 20 DSM-5 PTSD criterion symptoms in the male subgroup. The short code is defined as the same as Figure 1. (b) Node strength centrality estimates for the 20 DSM-5 PTSD criterion symptoms in the female subgroup. The short code is defined as the same as Figure 1.

subgroup were examined; results are presented in Figures 4(a) and 4(b). Figure 4(a) shows the edge weight bootstrap, which revealed that 95% confidence intervals for the edge weights were mostly overlapping, indicating that considerable accuracy was estimated in the network. Figure 4(b) represents the subset bootstrap; the CS coefficient was 0.28 for node strength. As mentioned in Methods, the coefficient could not be below 0.25 and preferably above 0.5. Therefore, this network had tolerable stability. For details about accuracy and stability analyses for this network, readers may view Figure S1 to S4 in Supplementary material, including edge weight significance tests (testing for significant differences for all edges) and centrality difference tests (testing for centrality differences for all nodes). Similarly, the accuracy and stability of the 20 PTSD symptom network (F1) in the female subgroup were examined, and results are presented in Figures 4(c) and 4(d). Figure 4(c) shows that F1 had considerable accuracy. Figure 4(d) indicates that F1, with an edge coefficient of 0.44 and CS coefficient of 0.21, slightly under 0.25, had a slightly bad stability for centrality estimate.

4. Discussion

This study conducted a network analysis on COVID-19-related PTSD symptoms among Chinese adults with scores that met PTSD's diagnostic criteria. Detailed comparison of the PTSD network between men and women found that negative connections among symptoms existed only in women. Our results shed light on the prevention and intervention of PTSD related to COVID-19 in the future.

4.1. PTSD Network in the Male Subgroup. In the current study, PTSD symptoms were generally positively connected among each other. The five strongest edges in the network emerged between difficulty concentrating (E5) and sleep disturbance (E6); intrusive thoughts (B1) and emotional cue reactivity (B4); irritability/anger (E1) and self-destructive/reckless behavior (E2); physiological cue reactivity (B5) and avoidance of thoughts (C1); and negative beliefs (D2) and negative trauma-related emotions (D4).

Among these connections, the strong connection between difficulty concentrating (E5) and sleep disturbance (E6) might exist because sleep disturbance may result in adverse outcomes such as lack of concentrating [38]. Armour et al. [39] indicated that most re-experiencing symptoms were linked either directly or indirectly with each other through other intrusive symptoms (i.e., nightmare was linked to emotional cue reactivity through flashbacks), and Jiang et al. [40] found strong connections between intrusive thoughts and nightmares and between flashbacks and emotional cue reactivity. These results revealed a high correlation among intrusive symptoms, which might explain the connection between intrusive thoughts (B1) and emotional cue reactivity (B4). Also, the connection between irritability/anger (E1) and self-destructive/reckless behavior (E2) may indicate reckless behavior as a way to release anger, while anger is often associated with improper self-control [41]. Moreover, the connection between physiological cue reactivity (B5) and avoidance of thoughts (C1) might be supported by the sensitization model of PTSD: people who experienced trauma could be sensitive to similar threats; thus, they might try to avoid thoughts about trauma but respond physiologically at the same time. What is more, evidence [42] indicated that trauma-related emotions might act as a buffer to negative emotions and indirectly lead to restructuring negative beliefs, which could explain the connection between negative beliefs (D2) and negative trauma-related emotions (D4). Also, it should be noted that these results matched the classification of the hybrid model of PTSD [34] to some extent, indicating mutual evidence between our study and Armour et al.'s study.

Importantly, the most central symptoms did not differ substantially from each other in their centrality and should be considered equally important despite the robustness of symptom centrality. The most central symptoms were difficulty concentrating (E5), flashbacks (B3), physiological cue reactivity (B5), self-destructive/reckless behavior (E2), and emotional cue reactivity (B4), and we concluded that they could be of greatest clinical significance in the male subpopulation who experienced COVID-19 outbreak. These central symptoms were similar in some degree to findings in previous studies: Jiang et al. [40] indicated that self-destructive/reckless behavior is of highest node strength; Armour et al. [39] showed that the most central symptoms were negative trauma-related emotions, flashbacks, detachment, and physiological cue reactivity; and McNally et al. [33] suggested that the most central symptoms were hypervigilance, concentration difficulties, and dreams about the trauma and future. These differences might result from the different types of traumas, which is similar with some networks differing in various stressful life events [43, 44]. Different intervals between the traumatic event and study events may have contributed to this discrepancy as well [40]. Notably, these potential central symptoms might be effective targets of treatment to facilitate the relief of most PTSD symptoms.

4.2. PTSD Network in the Female Subgroup. In the female subgroup, PTSD symptoms were generally positively connected among each other, expect for the connection between intrusive thoughts (B1) and self-destructive/reckless behavior (E2). The five strongest associations between symptoms were negative beliefs (D2) and negative trauma-related emotions (D4); blame of self or others (D3) and negative beliefs (D2); intrusive thoughts (B1) and emotional cue reactivity (B4); nightmares (B2) and flashbacks (B3); and intrusive thoughts (B1) and flashbacks (B3).

In these connections, the strong connections between negative beliefs (D2) and negative trauma-related emotions (D4) and the connections among intrusions symptoms could be explained as above. In addition, the connection between blame of self or others (D3) and negative beliefs (D2) may be explained because those with PTSD reported lower expectancies and higher daily negative affect [45], so they might have more negative beliefs as well as blame of themselves or others. Similarly, such connections revealed a consistent structure of PTSD symptoms with the hybrid model of PTSD [34], indicating mutual evidence between our study and Armour et al.'s work. Negative connection

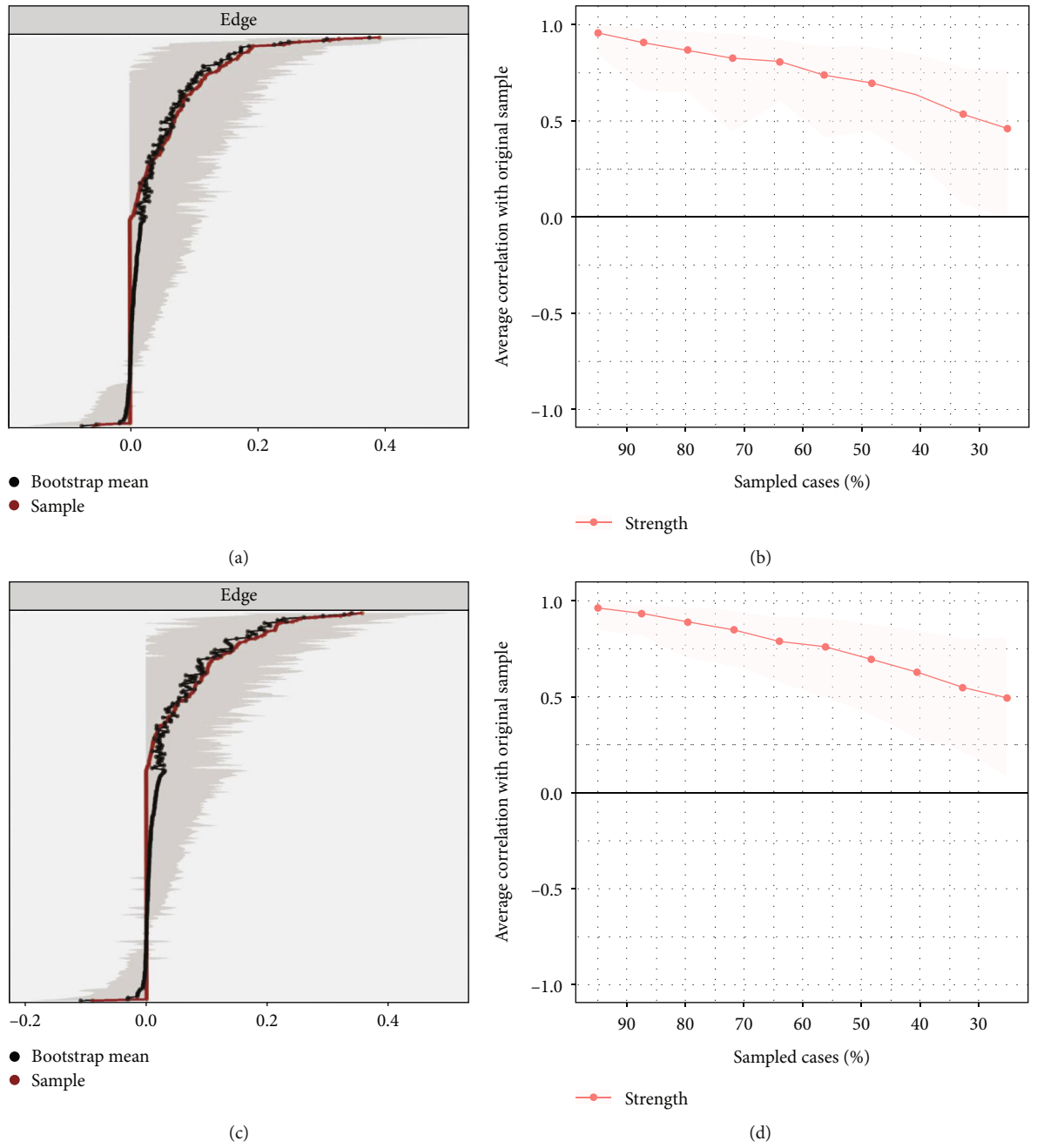


Figure 4: (a) Robustness of network of 20-item PTSD symptoms in the male subgroup. (b) Subsetting bootstrap for the 20-item PTSD network in the male subgroup. (c) Robustness of network of 20-item PTSD symptoms in the female subgroup. (d) Subsetting bootstrap for the 20-item PTSD network in the female subgroup.

between intrusive thoughts (B1) and self-destructive/reckless behavior (E2) could be explained through reckless behavior releasing the emotions [41] and reducing negative thoughts directly; or thought suppression might induce intrusive thoughts [46], and the reckless behavior indirectly reduces the occurrence of intrusive thoughts by releasing emotions.

Regarding centrality strength, the most central symptoms were self-destructive/reckless behavior (E2), avoidance of thoughts (C1), flashbacks (B3), intrusive thoughts (B1), and negative trauma-related emotions (D4). The differences among studies could be explained as above. However, it should be noted that the centrality strength is slightly lower than 0.25, indicating that the results of centrality should be treated cautiously.

4.3. Differences between the Male Subgroup and Female Subgroup. Results were both different and similar in both groups. For example, intrusive thoughts (B1) and emotional cue reactivity (B4) and negative beliefs (D2) and negative trauma-related emotions (D4) showed strong connections in both groups. However, the only negative connection occurred in the female subgroup: the connection between

intrusive thoughts (B1) and self-destructive/reckless behavior (E2). In addition, flashbacks (B3) and self-destructive/reckless behavior (E2) were the strong centrality symptoms in both groups. However, the most central symptom in the female subgroup was self-destructive/reckless behavior (E2) and in the male subgroup was difficulty concentrating (E5), and the orders of central symptoms were different between genders. These differences might generate from the different positions of the PTSD continuum [5] between the two populations. Further, gender differences might contribute to these findings. For example, the severity and performances of PTSD differed by gender [9], which could result in the different connections between symptoms in the subgroups. Also, males and females had different cognitive emotion regulation strategies and different attribution styles (i.e., females might attribute failure to themselves) [14]. Moreover, females could be more sensitive to emotion compared to males [47]. In a biopsychological view, compared with males, females could induce more cortisol dysregulation [48], hypothalamic-pituitary-adrenal axis activation [49], and fear-induced sympathetic activation [15]. Also, the females are more likely to develop internalizing defenses compared with the males [50]. These differences might explain that central symptoms and connections of symptoms in females were more related to personal thoughts or emotion (i.e., avoidance of thoughts), while in males, they were more related to actions (i.e., difficulty concentrating).

In conclusion, these results indicate that the same connections between symptoms were considerably stable in different groups, yet differences in strength indicated that symptoms might have different impacts on males and females. These differences might result in severity of trauma and the gender differences discussed above. Moreover, the connections of symptoms in both populations were consistent with the hybrid model of PTSD [34], which might classify the clusters of PTSD symptoms better than DSM-5. Possibly mutual evidence between our study and Armour et al.'s work and revealed potential clusters of PTSD symptoms related to COVID-19.

5. Limitations and Implications

Several limitations are present. First, the robustness analysis remained a moderate uncertainty when estimating edge weights and centrality parameters (especially in the female subgroup). More studies with a larger sample and better robustness are needed to elucidate the most central symptoms and the strongest edges. Secondly, data were collected through a web-based and self-report questionnaire; for example, the COVID-19 exposure was self-reported and no health system records were examined, which might bring selection bias. Also, current study used the online form rather than the psychiatric interviews to assess the status of mental disorders. Therefore, future studies should use specialized and structured interviews to collect their data and could take gold standard (e.g., psychiatric interviews) to assess the mental disorders. Thirdly, because the current study was cross-sectional, the causality between symptoms remained unclear. It was not clear whether a central symptom would cause the occurrence of other symptoms. Therefore, prospective studies are needed to solve this problem. Fourthly, this study did not take duration and severity of trauma into consideration. As the symptoms of PTSD might vary in severity and duration of trauma, future study could include them as well. Finally, some covariates were calculated with no weights in our study. For example, we did not take the weights of the eight questions about exposure to COVID-19, limiting the discovery of the exposure. Future studies could assess the weights due to different exposures and take into consideration the severity of the COVID-19 exposure. The same assessment could be applied to other related symptoms such as depressive symptoms.

For implications, clinicians could take strong connections between symptoms and central symptoms into consideration regarding intervention and treatment. To be specific, for strong connections, like intrusive thoughts and emotional cue reactivity, the intrusive thoughts might be more difficult to intervene on rather than the emotional cue reactivity; thus, the clinicians could focus more on emotional cue reactivity, and the alleviation of this symptom could break down other highly related symptoms like intrusive thoughts. For central symptom, the self-destructive/reckless behavior might be the core symptom, which could result in alleviation of other related symptoms in this network. In addition, the intervention and treatment might be different between males and females. For example, in female group, the self-destructive/reckless behavior might be the core symptom, while in male group, the core symptom might be difficulty concentrating.

6. Conclusion

This study indicates similar positive connections in both male and female populations. Further, the order of central symptoms differed. Due to these estimates of networks, we urge that self-destructive/reckless behaviors and flashbacks, as potential core symptoms of COVID-19-related PTSD, be given more attention in future pandemic-related psychiatric intervention programs.

Abbreviations

COVID-19: Coronavirus disease 2019
PTSD: Post-traumatic stress disorder
PCL-5: PTSD Checklist for DSM-5
CES-D: Center for Epidemiological Survey
PSQI: Pittsburgh Sleep Quality Index
CS: Correlation stability
IN: Intrusions
AV: Avoidance
NACM: Negative alterations in cognition and mood
AAR: Alterations in arousal and reactivity.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding authors on reasonable request.

Ethical Approval

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. The study protocol was approved by the Institutional Review Board of Peking University Medical Center, Beijing, China. Relevant guidelines and regulations carried out all methods.

Consent

After being informed about the survey's aims, all participants gave informed consent and joined the study voluntarily.

Conflicts of Interest

The authors report no conflicts of interest in this work.

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Supplementary Materials

Figure S1: bootstrap edge weight difference test between non-zero estimated edge weights in the network of 20 DSM-5 PTSD symptoms shown in Figure 1. Figure S2: bootstrap node strength difference test between node strength for the nodes of the network of 20 DSM-5 PTSD symptoms shown in Figure 1. Figure S3: bootstrap edge weight difference test between non-zero estimated edge weights in the network of 20 DSM-5 PTSD symptoms shown in Figure 2. Figure S4: bootstrap node strength difference test between node strength for the nodes of the network of 20 DSM-5 PTSD symptoms shown in Figure 2. Figure M3: estimated delta network of DSM-5 PTSD symptoms contains the change of PTSD symptom network upon including covariate in male group. Figure F3: estimated delta network of DSM-5 PTSD symptoms contains the change of PTSD symptom network upon including covariate in female group. Figure MF1: estimated delta network of DSM-5 PTSD symptoms between general group and PTSD subgroup. *(Supplementary Materials)*

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