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Network connectivity between anxiety, depressive symptoms and psychological capital in Chinese university students during the COVID-19 campus closure

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ABSTRACT

Background: In the context of the outbreak of COVID-19 within mainland China, to understand the mental health status of university students during campus closure, this study analyzes the relationship between anxiety, depressive symptoms, and psychological capital and to reveals their central symptoms.
Methods: A total of 12,945 university students were included in this study from April 10 to 19, 2022. Anxiety and depressive symptoms were measured by the seven-item Generalized Anxiety Disorder Scale (GAD-7) and two-item Patient Health Questionnaires (PHQ-2). Psychological capital was measured using the Psychological Capital Questionnaire (PCQ-24). The centrality and bridge centrality indexes were used to identify central and bridge symptoms, respectively. Network Comparison Test (NCT) was also administered to check whether network traits differed by gender and place of residence.
Results: The most influential node in this study was Trouble relaxing (GAD4), followed by Uncontrollable worry (GAD2) and Excessive worry (GAD3). The main bridging symptoms were Depressed mood (PHQ2), Psychological capital. There are no differences in the network structure of students by place of residence, while there are more significant differences in the network structure of students by gender.
Conclusion: Central and bridging symptoms may be the core symptoms that trigger or maintain the development of anxiety and depression among university students during the COVID-19 campus closure. Timely and reasonable interventions targeting these symptoms may help reduce depression and anxiety in this population. In addition, improving university students' psychological capital may likewise contribute to the development of their good mental health.

1. Introduction

On March 11, 2020, COVID-19, caused by Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2) (Ge et al., 2020), was declared a pandemic by the World Health Organization (WHO) (Cucinotta and Vanelli, 2020), leading almost all countries in the world to adopt some form of lockdown as an effort to reduce the spread of the new coronary pneumonia (Onyeaka et al., 2021; Romero-Blanco et al., 2020). Similarly, a public health emergency time level 1 response (i.e., the highest level of emergency public health alerts and responses within the national public health management system) was initiated within 31 provinces in mainland China to reduce the spread of pneumonia (Bao et al., 2020; Ma et al., 2020). Several measures have been taken, such as lockdowns in some cities (Han et al., 2021), and asking people to isolate at home and not to gather (Ma et al., 2020; Pan et al., 2020). Not only that, the campus closure policy was implemented in many cities (Fantini et al., 2020; Rajmil et al., 2021). Policies in response to the COVID-19 pandemic and to prevent the spread of the virus has affected the population, and the mental health consequences of the embargo have been of interest to scholars (Guessoum et al., 2020; Han et al., 2021; Rehman

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et al., 2021; Wang et al., 2022).

The prevalence of COVID-19 has brought the mental health of various affected populations into focus (Deng et al., 2021; Hou et al., 2021; Shah et al., 2021). The COVID-19 epidemic has exacerbated or created new stressors, including fear and worries about oneself or loved ones, restrictions on physical mobility and social activities due to isolation, and sudden and radical lifestyle changes (Brooks et al., 2020). It is essential to pay attention to the mental health of university students as a vulnerable group (Bruffaerts et al., 2018; Son et al., 2020). Several studies have found that the university student population experienced a higher risk of psychological problems such as depression and anxiety during the COVID-19 epidemic (Marelli et al., 2021; Shah et al., 2021; Zhang et al., 2021). It's also been shown that people with depression are more likely to have anxiety symptoms, and vice versa (Bai et al., 2021b; Tiller, 2013). Therefore, it is necessary to explore the relationship between depression and anxiety to alleviate the occurrence of depression and anxiety and the emergence of their co-morbidities.

Psychological capital is an individual positive psychological state of development and is characterized by self-efficacy, optimism, hope, and resiliency (Luthans et al., 2007), which has strong empirical associations with increased well-being and reduced mental health symptoms in adult samples (Finch et al., 2020; Zeng and Wei, 2021). More and more studies show that positive psychological capital as a protective factor can help people adjust and manage various stressors in their lives, thus effectively reducing anxiety, depression, and other psychological problems (Cui et al., 2021; Kan and Yu, 2016; Li et al., 2015). For example, studies of university students revealed that psychological capital can help university students effectively resist stress and reduce anxiety and depression (Prasath et al., 2022; Wu et al., 2019). So, exploring the specific association of psychological capital on anxiety and depressive symptoms can help alleviate the mental health of university students during and after school closure.

Network analysis is used to investigate the link between symptoms. In network theory, psychiatric disorders consist of interacting symptoms, and an accurate description of these interactions is critical to explain underlying psychopathological mechanisms and developing effective strategies for targeted interventions (Borsboom, 2017; Hofmann et al., 2016; Ren et al., 2021). Network analysis provides rich visual information on the relationship between various symptoms of different disorders and identifies central symptoms (i.e., symptoms that are strongly associated with other symptoms) in the network as well as bridge symptoms (i.e., symptoms that connect two psychiatric problems) (Epskamp et al., 2017; Jones et al., 2021; Wang et al., 2021). According to network theory, central symptoms are more likely to trigger other symptoms and play a significant role in the formation or maintenance of the disorder, and resolving core symptoms may lower the strength of other symptoms (Bai et al., 2021d; Bringmann et al., 2015). It has been convincingly shown that patterns and characteristics of mood disorders are influenced by socioeconomic background (Compton et al., 2006; Stompe et al., 2009). Therefore, the network structure between psychological capital, anxiety, and depressive symptoms should also be studied separately for populations in different social contexts.

In the context of the COVID-19 outbreak within mainland China, to understand the state of mental health of university students after campus closure, this study used network analysis to investigate the relationship between psychological capital, anxiety, and depressive symptoms among university students, and to reveal their central symptoms to provide a theoretical basis for reducing the occurrence of depression and anxiety among university students.

2. Methods

2.1. Study settings and participants

The data used in this study were obtained from the Student Mental Health Center at a university in eastern China, two weeks of static management (April 10–19, 2022) after COVID-19 arrived again in 2022 in the city where the school was located. During that period, online teaching was adopted at the university, and all students were allowed to carry out activities in the campus according to their actual needs (such as dining and purchasing daily necessities), but they were not allowed to enter and leave the campus gate at will. In this study, an electronic questionnaire was distributed to 13,325 current undergraduate students and a total of 12,945 data were returned and included, with a return rate of 97.15 %. There were no exclusion criteria. An electronic questionnaire was used to distribute on the WeChat and Tencent QQ platforms, where all students scanned the QR code and then filled out the questionnaire. Participants' IP addresses were used to identify and eliminate duplicate responses. If participants did not answer the current question, they did not move on to the next question; therefore, there was no missing data in this study.

The study was approved by the Ethics Committee of Xuzhou Medical University, and all participants in the questionnaire met the requirements for informed consent.

2.2. Measurements

The Psychological Capital Questionnaire (PCQ-24), created by Fred Luthans et al., was used to measure psychological capital (Luthans et al., 2007). The questionnaire contains four dimensions, self-efficacy, hope, optimism, and resilience, with 24 items. Each question has six options ranging from 1 (strongly disagree) to 6 (strongly agree). The total score range is 24–144, the higher the score, the higher the psychological capital. In this study, Cronbach's α for this scale was 0.955, indicating good reliability.

Two-item Patient Health Questionnaire (PHQ-2) Chinese version (Kroenke et al., 2003) was used to assess depression. Each question was assigned a score ranging from 0 (not at all) to 3 (nearly every day), with higher overall scores indicating more severe depression. The Chinese version of the seven-item Generalized Anxiety Disorder Scale (GAD-7) (Lin et al., 2021) was used to assess anxiety. Each item was given a score ranging from 0 (not at all) to 3 (nearly every day). GAD-7 total scores varied from 0 to 21, with higher numbers suggesting more severe anxiety symptoms. Cronbach's α for this scale in this study was 0.936.

2.3. Statistical analysis

2.3.1. Network estimation

In this study, network analysis was performed using the R-studio program (Version 4.1.0). According to network parlance, a network consists of "nodes" and "edges", and each symptom was treated as a node, and the correlation between two symptoms is considered as an edge (Borsboom and Cramer, 2013; van Borkulo et al., 2015; Zhao et al., 2021). Since the data in this study did not conform to a normal distribution, paired Spearman correlations were utilized to assess the network of associations showing the connection between psychological capital, depression, and anxiety and the Enhanced Least Absolute Shrinkage and Selection Operator (eLASSO) method was used (Friedman et al., 2008). The algorithm used the penalty parameters to obtain sparsity and used the Extended Bayesian Information Criterion (EBIC) (i.e., a measure of goodness of fit) to select the best set of neighboring factors for each node (symptom) (Chen and Chen, 2008; Epskamp et al., 2018; van Borkulo et al., 2014). The final network is automatically built after each node is linked to a few other nodes, and it shows the strength of the direct relationship between the nodes (van Borkulo et al., 2014). In this process, the R package "qgraph" (Version 1.6.9) (Epskamp et al., 2012) and "bootnet" (Version 1.4.3) (Epskamp et al., 2018) are used to complete this analysis and obtain a visual network. In the network layout, the color of the edges represents the direction of association (i.e., red edges for negative correlation and green edges for positive correlation) (Epskamp et al., 2012). The strength of the association between nodes is

indicated by edge thickness, and nodes that are more frequently and strongly associated with other nodes are positioned closer and in the center of the network (Cai et al., 2021).

We used three centrality indices to explore the importance of individual symptoms in the network: strength, closeness, and betweenness (Opsahl et al., 2010; Wang et al., 2020). Strength, which quantifies the significance of a symptom in the network, is more specifically the sum of edge weights that are directly connected to a node. Closeness is the inverse of the average shortest path length between a node and others, it measures how strongly a node is indirectly connected to other nodes in a network. Betweenness quantifies the significance of a symptom with other symptoms by indicating how often it is on the shortest indirect connection with another node (Cai et al., 2021; Wang et al., 2020). This analysis has relied on the "Plot" function in the "qgraph"(Version 1.6.9) package in R (Epskamp et al., 2012). Measures of centrality are presented as standardized values (z-scores). Similar to network centrality, we also analyzed the bridge centrality of each node using three metrics, including bridge strength, bridge closeness, and bridge betweenness. The central node of the bridge implies the importance of a symptom in connecting two mental health problems (Bai et al., 2021b; Cramer et al., 2010). The analysis is performed using the R package "networktools"(-Version 1.3.0) (Bai et al., 2021a). Additionally, predictability was calculated using the R program "mgm" (Version 1.2–12), which assesses how well a specific node is predicted by all of its neighbors (Haslbeck and Waldorp, 2018).

2.3.2. Network stability and accuracy

To confirm the robustness of the results, we utilized the R package "bootnet" (Version 1.4.3) to evaluate the stability and accuracy of the network (Epskamp et al., 2018). First, the node properties' stability is assessed using a case-dropping bootstrap procedure. The network is considered stable if most of the samples can be dropped from the dataset and the centrality index of the nodes does not change significantly. By computing the correlation stability coefficient (CS-C), the stability is measured. CS-C represents the largest number of cases that can be dropped, and the CS-C should be >0.25 and ideally >0.5 (Costenbader and Valente, 2003; Epskamp et al., 2018). Next, to estimate the accuracy of the edge weights, a nonparametric bootstrap method was used to calculate confidence intervals (CIs) (Bai et al., 2021c). Randomly resampling data observations created fresh datasets with 95 % CIs. A narrower CI indicates a more reliable network, whereas a large CI indicates less accuracy (Epskamp et al., 2018; Marchetti, 2019). Finally, the difference in network properties is estimated using bootstrapped difference tests. The test depends on a 95 % CI to identify if there is a difference between two edge weights or two node centrality indices (Epskamp et al., 2018).

2.3.3. Comparisons based on gender and residence

Considering the effect of gender and residence differences on depression and anxiety in previous studies, we compared the network structure of students by gender and residence. We employed a Network Comparison Test (NCT). This test is a permutation test to evaluate the differences between two networks (van Borkulo et al., 2015; Zhao et al., 2021). NCT is done on a sub-sample of the residency definition using 1000 permutations, a technique that compares the absolute sum of all edge weights between networks to measure the overall strength of the network (Mullarkey et al., 2019; Wang et al., 2020). The distribution of edge weights in each network is then compared to determine the network's structure. The analysis was performed using the "NetworkComparisonTest" (Version 2.2.1) R package (van Borkulo et al., 2022).

3. Results

3.1. Study sample

A total of 12,945 students (5533 males and 7412 females) participated in this survey, 43.6 % of whom were from rural areas. The mean age was 20.95 (SD = 1.66) years. The mean GAD-7 total score was 2.49 (SD = 3.71), the mean PHQ-2 total score was 1.49(SD = 1.41), and the mean psychological capital total score was 103.86(SD = 17.13) (Table 1). Descriptive statistics for all anxiety symptoms measured by the GAD-7 and all depressive symptoms by the PHQ-2 are shown in Table 2.

3.2. Network structure and stability

Fig. 1 shows the estimated networks, and the detailed edge weights are listed in **Table S1**. There was a positive correlation between all anxiety and depressive symptoms, while the relationship between psychological capital and anxiety and depressive symptoms was mostly negative. The ring-shaped pie chart in Fig. 1 represents the predictability of symptoms. The strongest link was seen between edge Anhedonia and Depressed mood (PHQ1-PHQ2). The edges between Restlessness and Irritability (GAD5-GAD6), Uncontrollable worry and Excessive worry (GAD2-GAD3), Nervousness and Uncontrollable worry (GAD1-GAD2), Trouble relaxing and Restlessness (GAD4-GAD5), and Excessive worry and Trouble relaxing (GAD3-GAD4) are then followed.

In the whole symptom network, Trouble relaxing (GAD4) had the highest strength among anxiety symptoms and is the dominant symptom, followed by Uncontrollable worry (GAD2) and Excessive worry (GAD3). Depressed mood (PHQ2) had the highest strength in depressive symptoms. The node with the lowest strength was Psychological capital. Centrality indices are seen in Fig. 2. In terms of bridge strength, the highest bridge strength symptom is Depressed mood (PHQ2), followed by Psychological capital and Nervousness (GAD1) (Fig. 3). The predictability values for each symptom are shown in Table 2. Node Trouble relaxing (GAD4) has the highest predictability in the network with an average predictability value of 0.592(SD = 0.155) for all nodes (i.e., an average of 59.2 % of the variance can be potentially explained by the nodes surrounding each node).

The results of the case-dropping bootstrap procedure analysis showed the high stability of the network. After dropping different proportions of the sample, the strength, betweenness, closeness, bridge strength, and bridge closeness values remained steady (Fig. 4). CS-C values of 0.75 for both strength and bridge strength ($r = 0.7$) , i.e., the findings did not change considerably after the samples were reduced by 75 % compared to the original results. The results of the nonparametric bootstrap method for estimating network edge stability showed that the weights of the edges in this sample were the same as those in the bootstrapped sample, indicating that the current network structure was stable (**Fig. S1**). As demonstrated in **Figs. S2 and S3**, the bootstrapped difference tests indicated that the majority of comparisons between edge weights and node strength were statistically significant.

3.3. Comparisons based on residence and gender

When comparing network models of students from various residences, there were no statistically significant changes in network global strength ($P = 0.722$) and the distribution of edge weights ($P = 0.871$) (**Figs. S4 and S5**). In contrast, when the differences in network structure were analyzed by gender, statistically significant differences were found

Table 1
Sample characteristics ($n = 12,945$).

Variables	Mean/N	SD/%
Age	20.95	1.66
Gender		
Male	5533	42.7
Female	7412	57.3
Residence		
Urban	7304	56.4
Rural	5641	43.6

Table 2
Descriptive statistics of the PC, PHQ-2, and GAD-7 items.

Item abbreviations	Item content	Item mean (SD)	Predictability
PHQ1	Anhedonia	0.87(0.814)	0.501
PHQ2	Depressed worry	0.62(0.728)	0.585
GAD1	Nervousness	0.54(0.691)	0.638
GAD2	Uncontrollable worry	0.38(0.653)	0.709
GAD3	Excessive worry	0.34(0.625)	0.705
GAD4	Trouble relaxing	0.34(0.622)	0.712
GAD5	Restlessness	0.29(0.592)	0.682
GAD6	Irritability	0.36(0.631)	0.642
GAD7	Feeling afraid	0.23(0.539)	0.547
PC	Psychological capital	103.86(17.131)	0.201

in the distribution of network global strengths ($P = 0.004$) and edge weights ($P < 0.001$). (**Figs. S6 and S7**). Further analysis of edge strength revealed that the edge Irritability and Feeling afraid (GAD6-GAD7), Anhedonia and Depressed mood(PHQ1-PHQ2), and Nervousness and Uncontrollable worry (GAD1-GAD2) connections were weaker and the edge Nervousness and Psychological capital (GAD1-PC) connection was stronger in the female network structure relative to the male students (Fig. 5 **and Table S2**).

4. Discussion

This is a study investigating anxiety, depressive symptoms, and psychological capital networks of Chinese university students during the COVID-19 outbreak campus closure. It was found that the most influential node in the anxiety, depressive symptoms, and psychological capital network was Trouble relaxing (GAD4), followed by Uncontrollable worry (GAD2) and Excessive worry (GAD3). These symptoms were the most likely to trigger or maintain anxiety and depressive symptoms as candidates. In this network, the bridge symptoms connecting anxiety, depressive symptoms, and psychological capital were Depressed mood (PHQ2), Psychological capital, and Nervousness (GAD1). In addition, in a comparison between students of different genders, female university students had the weaker edge in Irritability and Feeling afraid (GAD6-GAD7) , Anhedonia and Depressed mood (PHQ1-PHQ2), and Nervousness and Uncontrollable worry (GAD1-GAD2) connections and stronger edge Nervousness and Psychological capital (GAD1-PC) connections in their network structure.

Consistent with previous studies, the strongest edges were all within the respective entries for anxiety or depression, and the strength of the connections between symptoms within different disorders was weaker compared to the connections between symptoms of the same disorder (Bai et al., 2021a; Garabiles et al., 2019; Ren et al., 2021). In the present network, the most strongly connected edge was the connection between the two symptoms of depression (PHQ1-PHQ2), which is consistent with the results of a previous study (Bai et al., 2021b), but also differs from the results of some studies (Garabiles et al., 2019). The reason for this difference may lie in the different study populations.

Node strength analysis revealed that both uncontrollable worry (GAD2) and Excessive worry (GAD3) were the main symptoms of anxiety, depressive symptoms, and psychological capital network among university students who were locked on campus during the COVID-19 outbreak, and that they had a triggering or maintaining effect on the occurrence of various symptoms of depression and anxiety. Feelings of powerlessness, fear, apprehension, and annoyance about the epidemic were all common stressors among university students during the outbreak (Yang et al., 2021). Worry as a characteristic of a generalized anxiety disorder (Franklin et al., 2021), may be felt by students due to the interruption of class processes and being required to study online during the pandemic lockdown, while online courses have limited knowledge, poor teaching quality, and inefficient learning, thus triggering feelings of anxiety about the academic load (Bai et al., 2021a; Bai et al., 2021b; Gao et al., 2021). In addition, concerns about the health of family and friends, worries about future careers, problems with life depression, and reduced contact and support from interpersonal networks also were the main stressors for students (Elmer et al., 2020). Another core symptom that emerged in this study, Trouble relaxing (GAD4), also suggests that anxiety symptoms may be increased when students are locked in a fixed area for long periods while facing a disease that is present on a large scale, highly contagious, and potentially fatal.

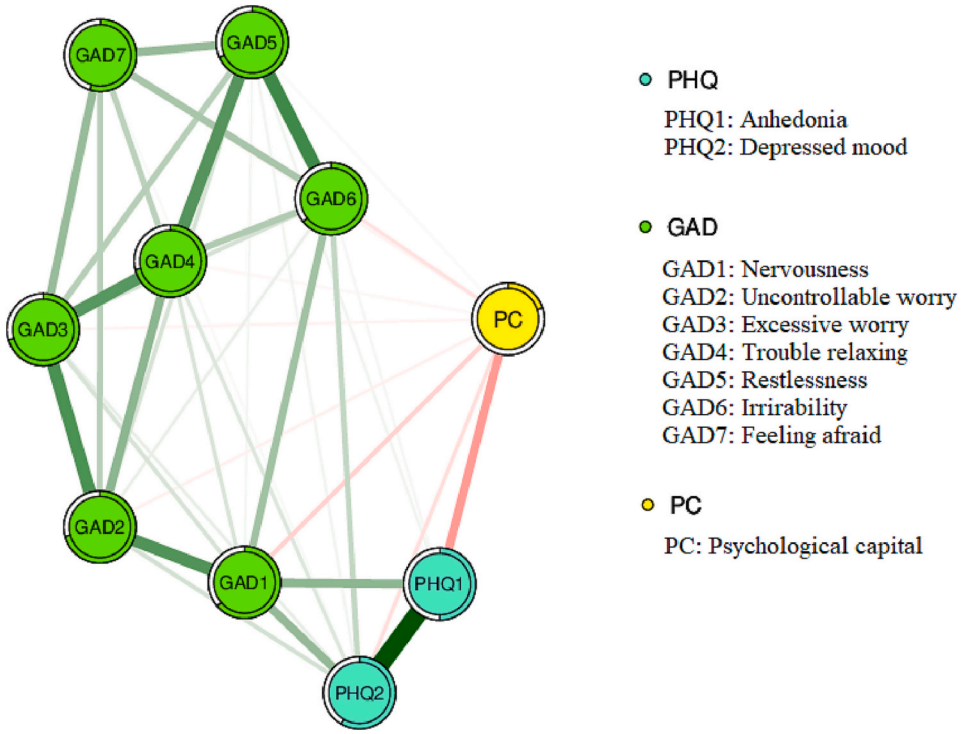

Fig. 1. Network structure of psychological capital, anxiety and depressive symptoms among university students.

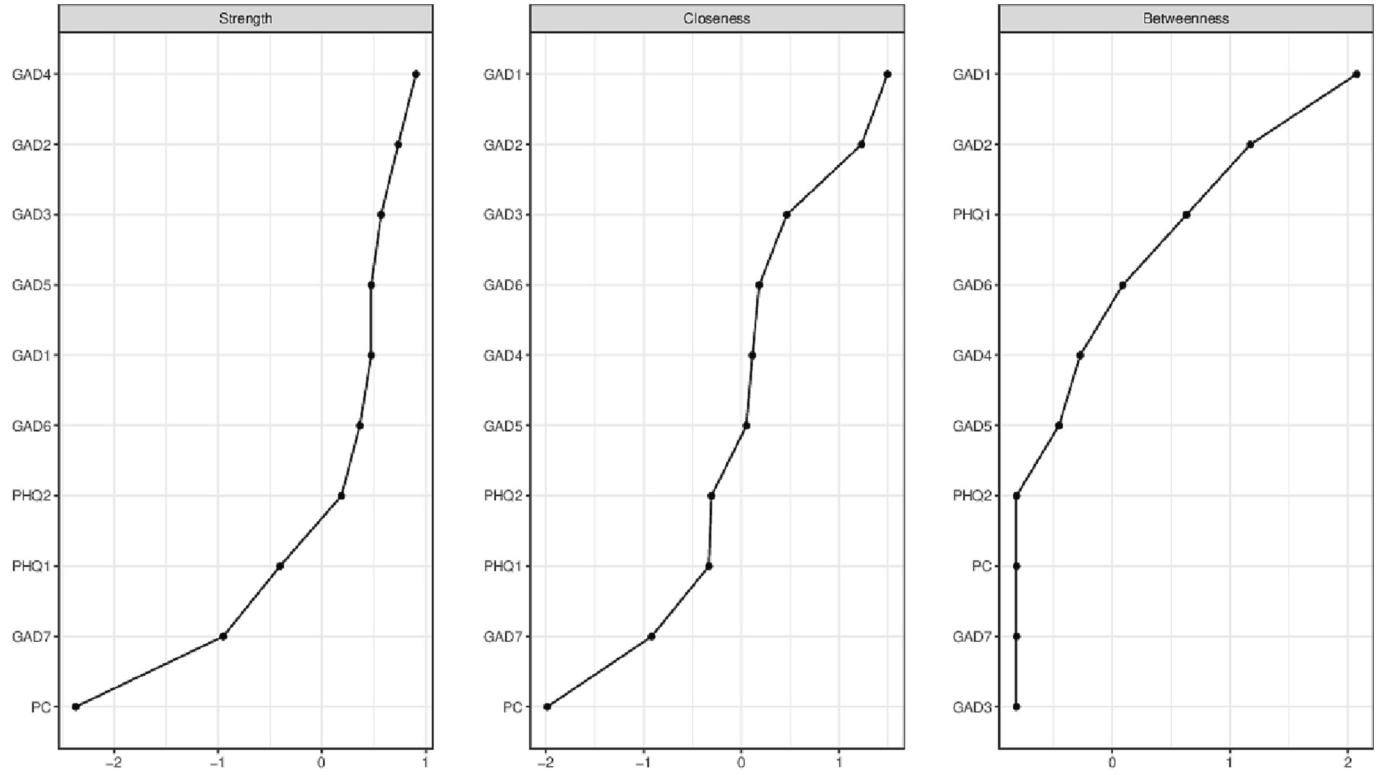

Fig. 2. Standardized centrality indices of network structure of psychological capital, anxiety and depressive symptoms (z-scores).

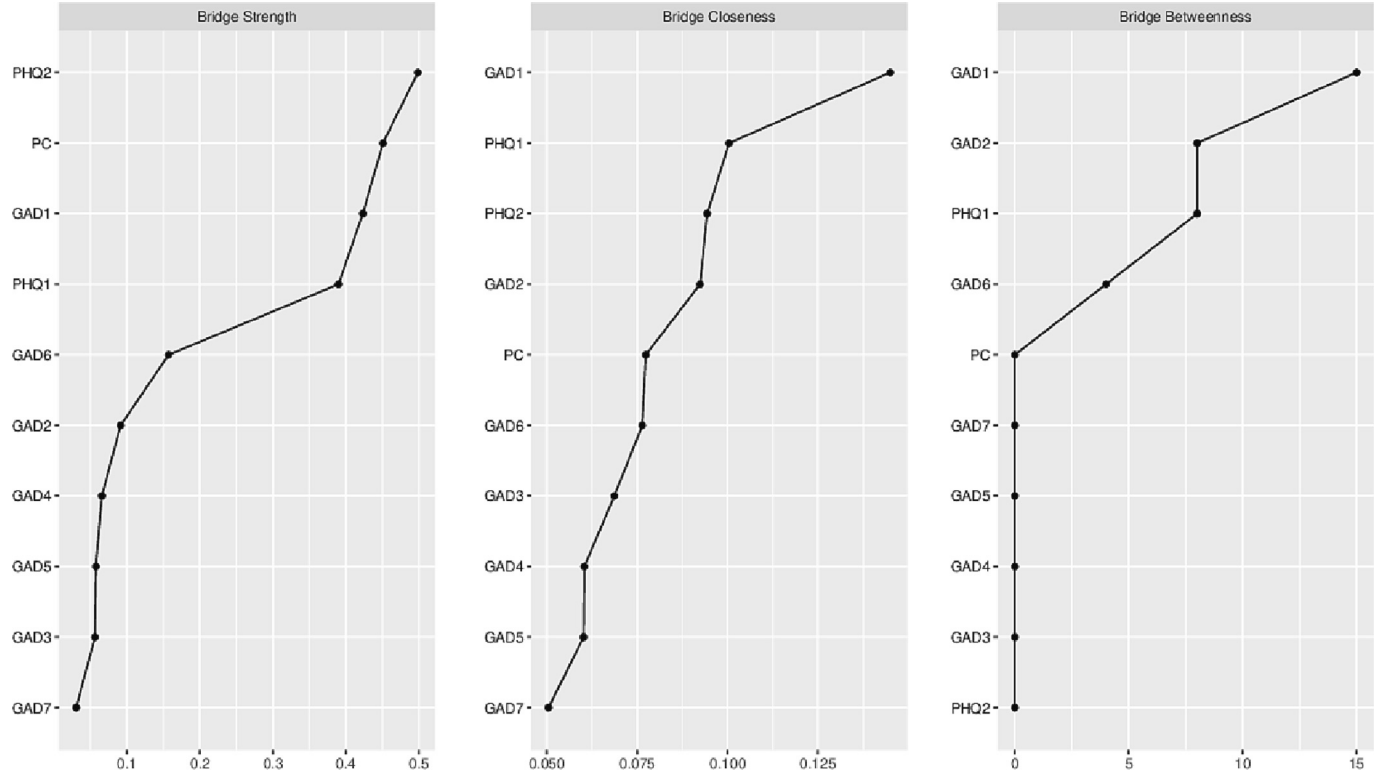

Fig. 3. Bridge centrality indices of the psychological capital, anxiety and depressive symptoms among university students (z-scores).

Bridging symptoms are considered in the network to be symptoms that connect two psychiatric symptomatology, and these symptoms can enhance the risk of symptom transfer from one psychiatric problem to the other (Epskamp et al., 2017; Jones et al., 2021). The depressive symptom Depressed mood (PHQ2) is the most significant bridge symptom in this anxiety, depressive symptoms, and psychological capital network, followed by Psychological capital and society symptom Nervousness (GAD1). This is completely in line with the findings of a

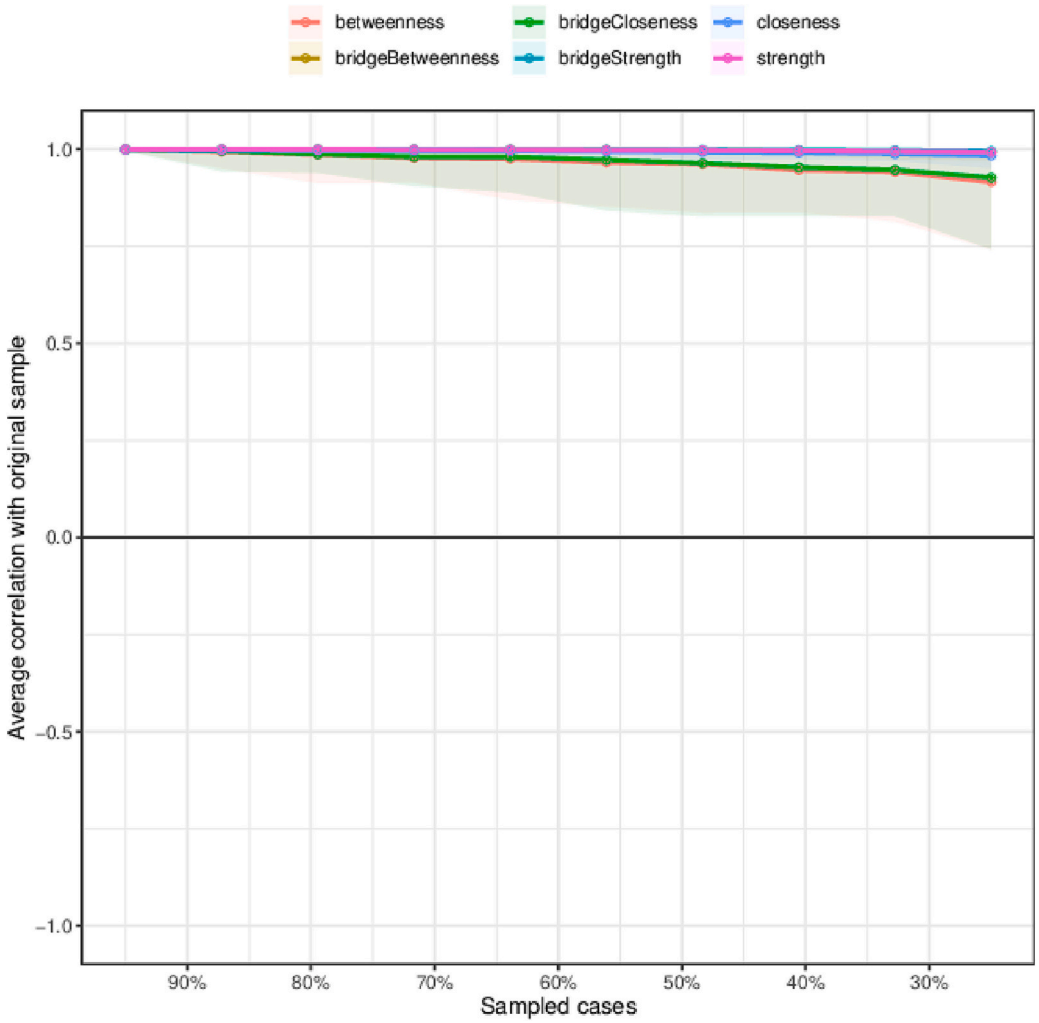

Fig. 4. The stability of network structure by case dropping bootstrap.

prior study of nursing students (Bai et al., 2021b). In this study, we suggest that appropriate interventions targeting Depressed mood (PHQ2) and Nervousness (GAD1) in a university student population may be effective in alleviating the development of co-morbidity between depression symptoms and anxiety symptoms.

Meanwhile, this study also found a negative correlation between the scores of psychological capital and most symptoms of depression and anxiety. Psychological capital theory suggests that psychological capital is a positive psychological resource that determines an individual's mental health and behavior (Cao et al., 2022; Luthans et al., 2007). It can increase individual satisfaction and well-being and combat stress, burnout, and depressive states (Avey et al., 2009; Liu et al., 2012; Liu et al., 2013). Furthermore, it has been shown that psychological capital components are positively associated with individuals' emotional functioning (Liu et al., 2013). For example, self-efficacy is considered an important positive psychological state that is associated with depression and anxiety. Previous research has found that higher self-efficacy scores among nurses and patients with advanced cancer are associated with fewer symptoms of depression and anxiety (Chang et al., 2011; Mystakidou et al., 2010). Hope can be a positive resource for individuals to fight negative emotions such as depression and anxiety, while also protecting them from the perceptions of being vulnerable and unpredictable. For instance, cancer survivors with higher levels of hope had lower levels of depression and anxiety (Tae et al., 2012). Moreover, psychological capital possesses high bridge strength in this study and it plays a key role in the co-morbidity of depression and anxiety. Therefore, it is necessary to improve the psychological capital of university students to reduce the occurrence of depression and anxiety. However, in this study, the strength value of psychological capital was at the lowest in the network, suggesting that we should pay attention to other factors that affect university students' anxiety and depression symptoms while paying attention to their psychological capital, to better prevent and reduce the occurrence of depression and anxiety symptoms.

Several limitations need to be noticed in the explanation of this study. First, this study, as a cross-sectional research, could not identify the causal relationship between these symptoms. Second, this study only investigated the anxiety, depressive symptoms, and psychological capital status of university students at the time of the outbreak of COVID-19 and could not make a well-established comparison with the situation before the outbreak. Third, all sample information in this study was obtained from individual self-reports, and there may be information bias in the process of information collection. Fourth, a proportion of these students surveyed may have suffered from mental health disorders but were not excluded, and the relationship between psychological symptoms or characteristics may be influenced by a psychiatric diagnosis.

5. Conclusion

In conclusion, network analysis revealed that Trouble relaxing (GAD4) Uncontrollable worry (GAD2), and Excessive worry (GAD3) were the main central symptoms. Depressed mood (PHQ2) and Nervousness (GAD1) were the main bridging symptoms in university

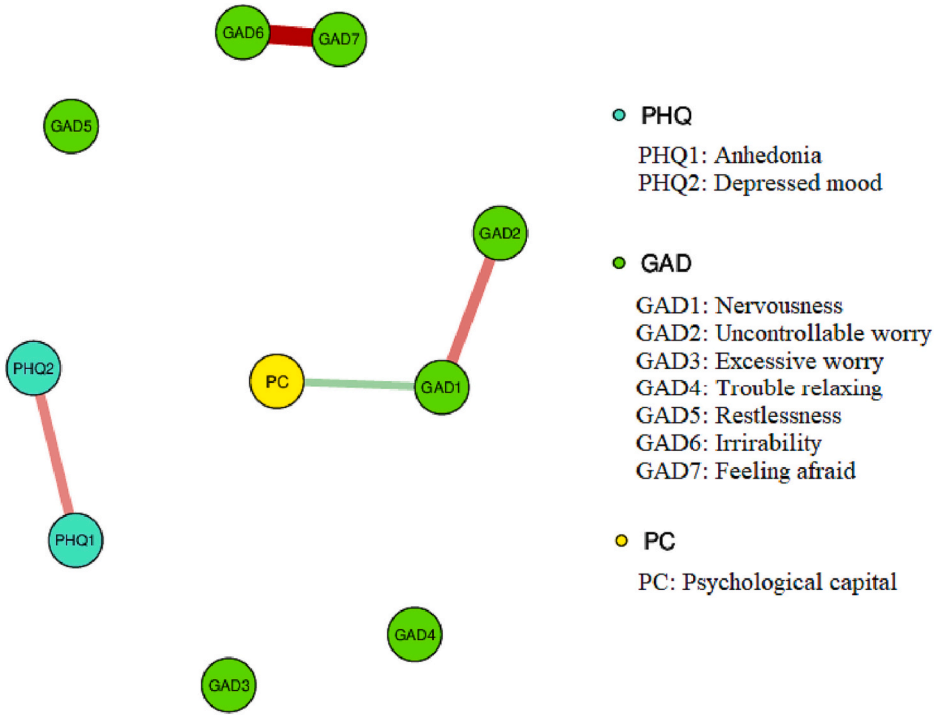

Fig. 5. Male and female university students showed significantly different edges.
Note: The blue node denotes the PHQ-2 item, the green node denotes the GAD-7 item, and the yellow node denotes psychological capital. Green edges indicate increased connections between symptoms in the female network structure compared to those in the male student network, and red edges indicate decreased connections between symptoms. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

students during the COVID-19 outbreak. These symptoms may be the core symptoms that trigger or maintain the development of anxiety and depression. Timely and reasonable interventions targeting these symptoms may help reduce depression and anxiety in this population. In addition, enhancing the psychological capital of university students may likewise contribute to the development of their good mental health.

Ethics statement

The Ethics Committee of Xuzhou Medical University gave its approval for this research, which was carried out in conformity with the Declaration of Helsinki.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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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.2023.02.087.

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